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SANITARY AND APPLIED CHEMISTRY

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TORONTO

A TEXT-BOOK OF SANITARY AND APPLIED CHEMISTRY

OR

THE CHEMISTRY OF WATER, AIR, AND FOOD

BY

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FOURTH EDITION REVISED

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PREFACE TO FIRST EDITION

The object of this work is to furnish a textbook upon applied chemistry that is suitable for use by those students who have had a course in general chemistry, such as is usually completed in a good high school or in the earlier years of a college course. The particular phase of applied chemistry treated is that which pertains to the daily life of the household, but the subjects considered do not by any means cover the whole field of what might be called chemistry applied to daily life, but only the most important topics.

Although primarily intended for use as a textbook, much scattered material is here collected from Government Reports and elsewhere, so that it is believed the book will prove valuable for general information and reference. The difficulty of condensing, without sacrificing something in clearness, is thoroughly recognized.

Some simple reactions in general and organic chemistry have, it is true, been introduced, but it is believed that they are of a kind to be readily understood by students, with a little explanation from the instructor. It would be well to supplement the text by lectures on the topics studied and also to give time for discussions.

The author believes that a practical method for teaching the subject, if a sufficient number of books of reference are at hand, is to outline topically the subject to be studied and require a preparation on those topics from the student.

It has been the intention of the author to introduce enough facts to render the subject intelligible and readily

comprehended, and not to burden the pages with details which belong properly to a more voluminous treatise on the subject.

One of the most important features of the book is the introduction of experiments, which are distributed throughout the text and which it is believed will very materially aid the instructor who may have occasion to direct the work of the students. These experiments are suggested by several years of experience with classes in Sanitary and Applied Chemistry, and they are of such a character as can be performed in any chemical laboratory and with a moderate amount of inexpensive apparatus. More difficult experiments, which would involve a knowledge of quantitative analysis, have been purposely omitted. The instructor can add more experiments, if sufficient apparatus is at hand and the time allotted to the course will permit.

The first part of the book is devoted to water, air, heating, lighting, and ventilation, — to those practical problems with which we come in contact every day; and the second part is occupied with a discussion of foods and beverages. In the latter section, although many adulterants are pointed out and the simpler tests for them are given in the experiments, no attempt is made to do the work, which properly belongs to the trained microscopist or analytic chemist.

For many valuable suggestions, which were made while the book was going through the press, and for assistance in reading proof, the author is especially indebted to Professor J. T. Willard, Dr. James Naismith, Professor Isabel Bevier, Professor M. A. Barber, Dr. H. P. Cady, Dr. W. D. Bigelow, Professor W. C. Hoad, and Mrs. A. T. Bailey.

PREFACE TO THE FOURTH EDITION

In preparing this edition the text has been corrected, much of it has been rewritten, and distinctive headlines have been added wherever it seemed that greater clearness could be attained. The chapters on Purification of Water Supplies and on Sewage Disposal have been brought down to date, and a chapter on Textiles and one on Poisons and their Antidotes have been added.

Instructors who use this book will find that an occasional visit, with the class, to some industrial establishment will add greatly to the interest. In almost every community there may be found gas, water, or electric light plants, and ice plants, bakeries, confectionaries, canning factories, creameries, and vinegar factories are common. It is an excellent plan also to visit and report on the heating and ventilating systems in school buildings, churches, large halls, and theaters, and to make tests upon the composition, temperature, and humidity of the air which is supplied.

In the laboratory work the student should be required to write out full descriptions of all the work performed, with conclusions upon the results obtained. This is the only way to make the laboratory work of any permanent value.

The author is indebted to Professor C. C. Young for valuable assistance in preparing this edition.

Lawrence, Kan.,
April 1, 1917.

CONTENTS

PAGE

INTRODUCTION xxv

PART I

SANITARY AND APPLIED CHEMISTRY

CHAPTER I

THE ATMOSPHERE

History — Proof that air has weight — Experiments of Galileo, Torricelli, and Lavoisier — Experiments by Cavendish and by Bunsen, Leroy, and Regnault — Recent discoveries by Ramsay and Rayleigh — Methods used for detecting argon and helium — Composition of the air — Experiments to illustrate composition of air — Proof that air is a mechanical mixture — Methods used for analysis of air — Oxygen in expired air — Moisture in the atmosphere — Proof that moist air is lighter than ordinary air — Experiments illustrating the presence of moisture in air — Carbon dioxid in free air and in closed rooms — Effect of impure air upon the system — Experiments to show the amount of carbon dioxid in the air — Nitric acid, ammonia, and other impurities in the atmosphere — Hydrogen peroxid — Ozone and its properties — Experiments upon ozone — The effect of carbon monoxid upon the system — Substances in suspension in the air — Methods of studying the dust of the atmosphere — Bacteria in city air — Micro-organisms not abundant at great altitudes — Infectious diseases readily propagated by dust — Decrease

PAGE

in tuberculosis — Vacuum cleaners — Experiments to show presence of arsenic in papers and fabrics — Injurious trades — Composition of ground air — Source of the impurities in ground air — Effects of ground air upon the system — Offensive gases . . 1

CHAPTER II

FUELS

History — Combustible elements in fuels — How heat is produced by combustion — Cellulose, the basis of ordinary fuels — Wood as fuel — Amount of water in different woods — Effect of drying upon wood — Composition of wood ashes — Charcoal — Method of making charcoal — Peat — Occurrence and preparation — Coal — Characteristics of different kinds of coal — Composition of different coals — The analysis of coals — Briquettes — Petroleum coke — Natural and artificial gases as fuel — Advantages of gas as fuel — Burners used with gas — Composition of natural gas — Gasoline — Kerosene — Wood alcohol — Grain alcohol 26

CHAPTER III

HEATING AND VENTILATION

Common methods of heating — Use and economy of the fireplace — The stove as a heating device — Use of the hot-air furnace — Use of steam with direct and indirect radiation — Advantages of hot-water heating — Electricity as a source of heat — Ventilation — Why little attention is paid to this subject — Necessity for ventilation — Amount of air used up in respiration — Heat retention a cause of discomfort — Contamination of air by lights — Properties of impure air — Amount of fresh air necessary to health — Crowd poisoning — Conditions necessary for good

PAGE

ventilation — Mechanical system of ventilation — Devices used for ventilating ordinary rooms — Experiments upon air currents and temperature . . 39

CHAPTER IV

LIGHTING

Sources of artificial light — Solid, liquid, and gaseous light-producing substances — The candle flame — Experiments with the candle flame — Use of gas for illuminating purposes — History of the development of artificial light — Candles as a source of light — Composition of candles — Method of making candles — Use of kerosene for lighting — Sources of coal oil and method of making — Distillates from Pennsylvania petroleums — Adulteration of kerosene — Experiments to show the flash point of oils — History of illuminating gas — Method of making gas — By-products in gas manufacture — Method of making water gas and its properties — Preparation and properties of air gas — Pintsch gas — Blaugas — Calcium carbid and its use in making acetylene — Use of acetylene on automobiles — Composition of illuminating gases — Experiments upon coal gas — Experiments upon acetylene gas — Lamps used for the burning of oils — Incandescent gas lights — Method of making mantles and their composition — Advantages of incandescent lights — Electric lights — The ideal light of the future — Table of light efficiencies . . . 54

CHAPTER V

WATER

Impurities in water — Source of impurities in water — Character of rain, river, lake, and well waters — Mineral waters — Experiments upon mineral substances in water — Hard waters — Disadvantages of

PAGE

the use of hard water — Experiments on hard water — Organic impurities in water — Source of these impurities — The sanitary analysis of a water — Meaning of the presence of free ammonia, albuminoid ammonia, nitrates, nitrites, and chlorin in a drinking water — Experiments to determine the quality of water — Analysis of city water supplies — Table — Drinking water and disease — Effect of suspended matter in water — Organic impurities in water — Illustration from the city of Messina — Illustration from the Valley of the Tees, England — Illustration from Plymouth, Pennsylvania — Illustration from Hamburg, Germany — Illustration from Lausen, Switzerland — Danger from sewage pollution — The cause of pollution of ordinary wells 71

CHAPTER VI

PURIFICATION OF WATER SUPPLIES

Natural purification — Processes used — Methods of purification — Coagulation and sedimentation — History — Artificial purification — Slow sand filtration — Construction of filters — Cleaning the filter — Rapid sand or mechanical filtration — Method of operation — Water softening — Reactions involved — Disinfection of water supplies — Use of hypochlorite of lime — Use of liquid chlorin — Use of ultra-violet light — Household purification of water — Domestic filters — Boiling the water — Use of ozone and of ultra-violet light for household purification — Effect of freezing — Water supplies of cities — Per capita amount supplied — Surface waters collected in impounding reservoirs — Water supplied by small lakes — Water supplied from the Great Lakes — Water supplied from rivers — Cities of United States supplied from rivers — Ground water supply — Cities supplied in this way — Disadvantages of ground water — Storage of ground water. 90

CHAPTER VII

Sewage: Disposal of Household Waste and Garbage

PAGE

Composition of sewage — Oxidation of sewage — Modern theories for purification of sewage — Disposal of sewage by dilution — The sewage of Milwaukee and Chicago — Disposal of sewage by irrigation — Intermittent filtration — The septic tank — The Imhof tank — The activated sludge process — Disinfection of sewage — Precipitation of sewage — Disposal of household waste — The use of the stove or furnace for disposal of waste — Burying in the soil — Methods used for disposing of waste in large cities — Cremation as used abroad — "Reduction" of garbage and utilization as a fertilizer — Municipal refuse 103

CHAPTER VIII

Textiles

Materials used — Origin of materials — Cotton fibers — Structure — Mercerized cotton — Flax (linen) — Method of treating to obtain fiber — Structure — Wool — Description of wool fibers — Wool grease — Scouring wool — Silk — How produced — Description of silk — Artificial silk — Pyroxylin silk — Cuprammonium silk — Viscose process — Reactions of fibers with alkalies and with acids — Differentiation between various textiles — Fire-proofing cotton — References 114

CHAPTER IX

Cleaning: Soap, Bluing, and Bleaching

Necessity for cleanliness — Cleaning materials act mechanically or chemically — Polishing powder — Borax — Ammonia — Cleaning leather, wood, etc. — Solvents for grease — Cleaning marble — Use of solvents upon household fabrics — Removal of grease by blotting paper, French chalk, fuller's earth — Treat-

PAGE

ment of paint spots with oil and turpentine — Sugar and acid spots — Ink spots — To clean tarnished silver — Cleaning polished brass and copper — Experiment to remove iron rust 123

Soap: History of the discovery of soap — Raw material used in its manufacture — Process of saponification — Method of making soap commercially — Mottled, toilet, transparent, and perfumed soaps — Scouring soaps and their use — Soft soap — No economy in the use of a cheap soap — Advantage of a well-dried soap — Theories in regard to the action of soap — The use of hard water — Experiments upon making soap and in testing its composition — Washing soda — Experiments to test a washing powder . . 128

Bluing: Use of indigo — Prussian blue for making liquid blue — Ultramarine and its use as a bluing material — Experiments with Prussian blue and with ultramarine — Aniline colors as used in liquid blues . . 136

Bleaching: Use of bleaching agents — Calcium hypochlorite — Hydrogen peroxid — Sulfur dioxid . . 138

CHAPTER X

Disinfectants, Antiseptics, and Deodorants

The necessity for using disinfectants and antiseptics — The importance of the sense of smell — Tests for disinfectants — How bacteria multiply — An ideal disinfectant — Use of the following disinfectants and antiseptics: Sunlight — Dry air — Dry earth — Charcoal — Experiments upon the action of animal charcoal — Dry heat and its use — Sulfur dioxid as a disinfectant — Carbolic acid and its value — Copper sulfate — Iron sulfate — Zinc chlorid — Potassium permanganate — Fire, the most effective means of destroying disease germs — Steam as used for destruc-

PAGE

tion of germs — Boiling water and how it may be used — Chlorid of lime, its value and use — Formaldehyde gas and the method of applying it — Corrosive sublimate and its value as an antiseptic . . . 140

CHAPTER XI

Poisons and their Antidotes

Opportunities for becoming accidentally poisoned — Chronic and acute poisoning — Poisons and corrosives — Treatment when poisoned with alkalies — With acids — Metallic poisons — Symptoms and antidote in case of copper poisoning — Treatment for zinc poisoning — Lead poisoning with method of treatment — Mercury poisoning — Arsenic, description and properties — Treatment — Antimony salts — Oxalic acid, with method of treatment in case of poisoning — Hydrocyanic acid — Phosphorus poisoning — Morphine poisoning — Strychnine — Aconite — Carbolic acid — Wood alcohol — Ptomaine poisoning — Carbon monoxid 152

PART II

CHEMISTRY OF FOOD

CHAPTER XII

Food

Definition of food — Distinction between food and medicine — Uses of food — Delicacy of the sense of taste — Experience has been our guide in selecting food — Variety of food — Value of a mixed diet — Selecting food suited to habit and employment — Reasons for cooking foods — Food used to build up the tissues

PAGE

and supply energy — Synthetic foods — Elements contained in the body — Amount of substances occurring in the body — Carbohydrate and nitrogenous foods — The cellulose, cane sugar, and glucose groups — Proximate substances contained in foods, viz. water, fat, carbohydrates, protein, organic acids, and mineral salts 161

CHAPTER XIII

Cellulose, Starch, Dextrin, Legumes

Occurrence of cellulose and its properties — Experiments upon cellulose — Sources of starch and amount found in various cereals — Wheat, its composition — Comparison of different grades of wheat — The composition and properties of wheat flour — Analysis of different kinds of flour — Milling products of flour — Corn — Composition, properties, and uses — Comparison of wheat and corn — Oats — Composition and peculiar characteristics — Rye — Its source, composition, and use — Barley — Its composition — Rice — Its cultivation, composition, and properties — Potatoes — History of the introduction of potatoes — Composition and value of potatoes — This tuber not suited for use as a staple article of diet — Composition of sweet potatoes — Cassava (tapioca) — Its source and method of manufacture — The source and method of preparing arrowroot — Properties of other starches, sago, *tous les mois*, etc. — Adulteration of starch and method used for the detection of adulteration — Legumes — Cultivation of the members of the Pulse Family — Properties of the legumes — Composition of peas, beans, and lentils — Experiments upon legumes — Value of legumes as a food — Bananas — Starch — Sources of commercial starch and method for making — Experiments upon starch

PAGE

— Dextrin and method of making — Gums — Inulin — Physical properties of starch — Experiments with starch grains — Chemical properties of starch — Experiments in making starch and to show its properties — Experiments upon dextrose — Experiments with diastase 170

CHAPTER XIV

Bread

Primitive method of making bread — Two general methods of making dough light — First, non-fermentation method; second, fermentation method — Bread not raised with fermentation: by the use of eggs, alcoholic liquors, ammonium carbonate, baking soda, baking soda and molasses, carbon dioxid, baking soda and hydrochloric acid, baking soda and sour milk, baking soda and cream of tartar — Baking powders — Cream-of-tartar powders — Phosphate powders — Alum powders — Experiments with baking powders — Bread raised by fermentation: first, by use of yeast; second, by use of leaven; third, by the salt-rising process — Composition and properties of yeast — Method of making yeast — Theory of use of leaven — What takes place in the salt-rising process — Chemistry of the fermentation of dough — Essentials to be noted in making good bread — Construction and use of the oven — Temperature used in baking — Difference between fresh and stale bread — Amount of bread that can be made from a given weight of flour — Composition of different kinds of bread — Difference between the crumb and crust — Starch alone will not sustain life — Value of a mixed diet to man — Bread a nutritious food — Value of white *vs.* whole-wheat bread — Patent flour —

PAGE

Stale bread and why it is wholesome — Corn bread — Why some bread is bad — Adulteration of flour and bread — Use of copper sulfate to make bread white — Use of alum as an adulterant — Experiments upon copper sulfate in bread — Experiments to detect alum — Occurrence of ergot in flour . . 201

CHAPTER XV

Breakfast Foods and Other Special Foods

Foods for infants and invalids — Breakfast foods and their composition — Conclusion in regard to the use of breakfast foods — Macaroni, vermicelli, etc., as foods — Composition of macaroni 229

CHAPTER XVI

Sugars

History and classification — Consumption of sugar in different countries — Different sugars known to the chemist — Classification of sugars — The sucrose and glucose groups — Members of the sucrose group — Sources of cane sugar — The sugar cane as a source of sugar — Cultivating the sugar cane — Extraction of the juice — Purification of the juice by the use of sulfurous acid — Concentration of the juice in the "triple effect" and in the vacuum pan — Use of the centrifugal — Treatment of the sirup — Making sugar from the sugar beet — History of the development of the industry — Use of the diffusion process — Concentration and purification of the juice — Manufacture of maple sugar — Adulteration of maple sugar — Sorghum sugar and its manufacture — Molasses — Sugar-refining — Methods adopted in the commercial centers — Use of the bone-black filter — Revivifying bone black — Use of the vacuum pan and centrifugal — Granulated sugar — Powdered and cube sugar — Experiments to show the properties of

PAGE

sugar — Composition of raw and of refined sugars — Food value of sugars — Maltose, its source and properties — Lactose, method of making and properties 235

CHAPTER XVII

Glucose or Grape-sugar Group

Processes used for the manufacture of glucose and its composition — Uses of glucose — Healthfulness of the product — Experiments upon glucose — Invert sugars — Levulose — Honey — Composition and properties of honey — Experiments with honey . 251

CHAPTER XVIII

Leaves, Stalks, Roots, etc., used as Food

Value of this class of nutrients — Carrots, parsnips — Turnips and beets — Leaves as food — Composition and value of cabbage — Greens — Asparagus — Rhubarb, etc. 257

The use of onions and leeks — Tomatoes and their use — Irish moss and its composition — Mushrooms and toadstools — The growing of mushrooms and their composition — The selection of the non-poisonous varieties 260

CHAPTER XIX

Composition and Food Value of Fruits

Some definitions — Composition of fruit at different periods of growth — Change in composition as illustrated by analysis of apples — The ripening of fruit — Table showing composition of various fruits — Value and properties of the different ingredients in fruits — Malic acid, citric acid, tartaric acid with experiments — Effect of cooking upon fruits . . 263

PAGE

Jams and jellies and their adulteration — Opportunity for falsification in this material — Substitutes for jam and jelly upon the market — Experiments upon adulterated jellies — Fruit sirups — Flavoring extracts . 270

CHAPTER XX

Edible Fats and Oils — Food Value of Nuts

Composition of edible fats — Digestion of fats and oils — Amount of fat in different vegetable and animal substances — Use of cottonseed oil in cooking — Use of oil of cocoanut — Lard — Method of making the different grades, such as refined lard, kettle-rendered lard, neutral lard — Adulteration of lard — Manufacture of compound lard, cottolene, cottosuet — Use of nuts as food — Composition of the more important nuts — Removal of excess of oil from some varieties — Value of almonds for food — Use of peanuts as food 274

NITROGENOUS FOODS

CHAPTER XXI

Meat

Concentration of nitrogenous food by animals — Importance of nitrogen in the animal body — Classification of nitrogenous bodies — Functions of albuminous substances — Structure of lean meat — Constituents of meat — Composition of beef — Use of animal food in different countries — Cooking of meat by roasting, broiling, etc. — Beef extracts and their value — Different kinds of meat similar in composition — Fish as a cheap and nutritious food — Characteristics of this food — Fat and lean fish — Use and food value of oysters — Danger from trichina, tapeworms, etc., in pork — Experiments upon cooking meat . . . 280

CHAPTER XXII

Eggs

PAGE

Composition of egg white and egg yolk — Use of eggs as food — Methods of preservation — Desiccated eggs — Proper method for cooking eggs — Experiments with egg white and egg yolk 291

CHAPTER XXIII

Milk, Cheese, and Butter

Composition of milk of different animals — Composition of various kinds of milk — Experiments upon the specific gravity of milk — Composition of butter fat and method for its determination — Use of koumiss — Experiments to determine amount of butter fat and total solids — Cause of the souring of milk — Experiments with coagulants — Methods of raising cream — Sterilized and pasteurized milk — Condensed milk — Its composition — Nature of modified milk and how it is prepared — Experiments to detect milk adulteration — Cheese — The methods for its manufacture — Description of different kinds of cheese — Table showing composition of various cheeses — Butter and butter substitutes — Conditions necessary for making good butter — Renovated or process butter — Manufacture of oleomargarin — Materials used in making oleomargarin — Attitude of the government toward this industry — Experiments with butter . 295

CHAPTER XXIV

Non-alcoholic Beverages

General demand for beverages of this class — Amount of tea, coffee, and cocoa used in the United States — Source of tea — Composition of green and black tea

PAGE

— The most important constituents and their properties — Experiments upon making a decoction of tea and its properties — Paraguay tea — Coffee-leaf tea — Coffee — History of its growth — Method of cultivation and preparation of the berry — Analysis of coffee — Effect of roasting — Adulteration of ground coffee — How to make the beverage — Coffee substitutes — Cocoa and chocolate — History of this product — Method of growing the nuts — Composition of chocolate, cocoa, cocoa shells — Value of cocoa as a food material — Manufacture of chocolate — Experiments upon chocolate — The cola nut — Comparison of the effect of the non-intoxicating beverages upon the system 312

CHAPTER XXV

ALCOHOLIC BEVERAGES

Use of alcohol from the earliest history of the world — Properties of alcohol — Consumption of alcoholic liquors in different countries — Classification of alcoholic beverages into fermented, malt, distilled liquors, and cordials — Per cent of sugar in different fruits — Wine — Source of wine — Method of making — Fermentation — Aging wine — Chemical reaction involved in wine making — Changes produced by aging — Composition of various wines — Classification of wines — Why grapes make better wines than other fruits — Adulteration and plastering of wines — Diseases of wines — Experiments upon wine — Cider — Method of making — Adulteration and falsification — Beer — Method of making malt — Chemical changes involved in manufacture of beer — Composition of some malted liquors — Experiments upon beer — Distilled liquors — Definition — Method of making alcohol — Distinction between brandy, whisky, rum, and gin — Adulteration of fermented liquors — Liqueurs — Cordials — Physiological action of alcohol 327

CHAPTER XXVI

Food Accessories

PAGE

Difference between condiments and spices — Common adulterants of ground spices — Source and properties of cloves, cinnamon, pepper, ginger, nutmeg, mustard — Experiments upon spices — Vinegar — Chemical changes involved in its manufacture — Material used, such as wine, fruit, spirits, malt, etc. — Quick vinegar process — Experiments upon vinegar — Salt — Occurrence of salt in different parts of the world — Method of obtaining the commercial salt — Composition of average samples — Uses of salt . . . 345

CHAPTER XXVII

Preservation of Foods — Coloring of Food Products

Method of preservation of food formerly adopted and those in use at present time — Conditions favoring fermentation and decay — Preservation by canning — Canning as carried on in large manufactories — Experiments upon preservation of food — Use of tin cans — Experiments upon the composition of the can — Recent use of chemical preservatives — Objection to the use of these substances — Use and method for detection of borax, sodium benzoate, salicylic acid, sodium sulfite, and formaldehyde — Coloring of food products — Objections to this custom — Use of copper to give a green color to pickles — Experiments upon food coloring 354

CHAPTER XXVIII

Economy in the Selection and Preparation of Food — Dietaries

Proper methods for cooking food — How starch is affected by heat — Changes which fats undergo in cooking and

PAGE

the effect of heat upon them — Leguminous foods and how they should be cooked — A large amount of nutriment at small cost — Comparison of vegetable and animal foods — Relation between cost of the food and its nutritive value — Importance of cooking each food in the best way — The use of a steam cooker in economizing fuel — The Aladdin oven as an economic kitchen utensil — The fireless cooker . . . 365

Dietaries: History of the study of the composition of food — Experiments carried on by the United States government — Definition of calories — Fuel value of different classes of nutrients — Use of the respiration calorimeter — A study of the food of different individuals or classes — Table showing dietaries used in the United States and abroad — Standard dietaries as estimated by different authorities — The use of smaller amounts of proteids than the accepted dietary would indicate — The ideal ration — Cost of food and nutritive ratio — Per cent of income expended for food by people of different classes 370

INTRODUCTION

A KNOWLEDGE of the science of chemistry is necessary for a proper understanding of so many of the other sciences that it is not strange that this subject is so often required of students in the lower grades. To know even the rudiments of physics, botany, biology, geology, mineralogy, or physiology, the student must have a fair knowledge of chemistry.

When we consider, however, the arts that have to do with modern living, — the eating, drinking, and breathing, all of which may be prosaic enough in their way, — it is evident that the foundation study here also is a knowledge of the composition of the substances surrounding us.

A knowledge of the relations to health of pure air, unpolluted water, and wholesome food will have much to do with improvement in sanitary conditions, not only of students themselves, but, through them, of the people at large. The air is usually said to be free, but pure air and sunshine cost money, as the crowded tenements show. The best lighted and ventilated rooms are worth the most. Since physicians agree that impure air is a predisposing cause of a large per cent of diseases, it is of the greatest importance that a knowledge of the

danger from this source be diffused among all classes of people.

Water is furnished by the well or cistern at the farm or the isolated country house, and for a very large population by a corporation or by the municipality itself. Those who use the water from the private source of supply or those who furnish it to the multitude of the city, should know how water becomes polluted and how to guard against disease from this source.

The food supply is obtained from various sources. There is a growing tendency to have food prepared outside the household, and the family learn to depend on the baker, the grocer, and the packing house for their food. With this tendency comes the temptation to those who furnish food ready prepared or dressed, to falsify or adulterate it, because they have the opportunity.

It is certainly time that the people should have some practical knowledge of food and medicine. Without this knowledge they will continually be imposed upon by those who have something to sell which may be worthless as a food, or dangerous as a medicine.

Just as society claims the right to protect itself against epidemics, against polluted water, and against smoke nuisances, so it is learning that it also has the right to protect itself against bad food. The United States and the various state and city governments have aided the people generously for the past twenty-five years, and by their published analyses, bulletins, and other literature have assisted notably in molding public sentiment in favor of wholesome and unadulterated food. The foundation of the present movement seems to be publicity.

Schools and colleges are beginning to see their opportunity to impart a kind of knowledge that is practical

and sane, and so we have the manual training school and the agricultural college, as well as instruction in domestic science in schools of a lower grade.

A thorough understanding of the facts of applied chemistry will not make the skilled workman, nor will the theories of chemistry make the accomplished cook, but a broad and thorough knowledge of the underlying principles will go very far toward developing common sense in hygiene and in the selection and preparation of food.

PART I

SANITARY AND APPLIED CHEMISTRY

CHAPTER I

THE ATMOSPHERE

HISTORY

The early philosophers in the time of Aristotle, 350 B.C., thought there were four elements, — earth, air, fire, and water, — and that each of these had special properties, and they also believed that the air had weight. For sixteen hundred years comparatively nothing was done except to theorize in regard to the properties of air. Then Galileo, an Italian, showed that a copper globe filled with air under ordinary pressure weighed less than the same globe filled with compressed air. Galileo was fortunate in making the acquaintance of Torricelli, also an Italian, and at the death of the former, Torricelli carried on the experiments. He explained why it was impossible to raise water more than thirty-three feet in a tube by suction; that is, that there was not sufficient pressure of the air to force the water higher, and he also reasoned that a heavier liquid, like mercury, could not be raised as far as water. He tried this experiment and found that mercury could be raised only about thirty inches, and noticed that the relation between the

specific gravity of mercury and that of water was inversely proportional to the height to which the two liquids could be raised. That is, water can be raised 13.6 times as far as mercury.

The theory that air had weight, and kept the mercury or the water up in the barometer tube, was not fully adopted when Torricelli died. Pascal, a Frenchman, born in 1623, who followed these investigators, said that if their theory was true, a column of mercury would fall when a barometer was carried to an elevation, so he secured the services of a friend to carry a barometer to the top of a mountain, and the latter was delighted to find that as he ascended the mountain the mercury fell. It was left to Boyle, an Irishman, born in 1627, to use this apparatus, which he called a "barometer" (Gr. *baros, metron*), to measure the weight of the air.

All this time air was regarded as a simple element, and the next epoch in its study was the discovery, by Priestley and Scheele in 1774, that it contained the element oxygen. It was left for the French chemist, Lavoisier, to correlate the discoveries of several chemists, and to show that when oxygen was taken out of the air, the gas that remained was the so-called nitrogen, discovered in 1772 by Rutherford. Lavoisier noticed that by heating mercury in a confined volume of air the air was contracted one fifth in volume, and the mercury was covered with a red powder. The air that was left in the vessel would not support combustion. When the red powder, which is oxide of mercury, was afterwards heated, it gave off a gas whose volume was one fifth of the original air, and this gas would support combustion with great vigor.

Cavendish made a large number of experiments on the

air, but it was Bunsen, Le Roy, and Regnault who proved that air is not always of the same composition, though very nearly so, and that consequently it cannot be a chemical compound, but must be a mixture of different gases.

The third era is the recent discovery of argon (in 1894 and the years following), by two Englishmen, Lord Rayleigh and Professor Ramsay; and later helium and other gases were discovered in the atmosphere. The circumstances that led to the discovery of argon are interesting. Lord Rayleigh noticed that the weight of a liter of nitrogen obtained from chemicals, as by heating ammonium nitrite ($NH_4NO_2 = N_2 + 2\,H_2O$) is 1.2505 grams, but a liter of the so-called nitrogen obtained from the air weighs 1.2572 grams. It was impossible to account for this by assuming errors in the weighings, which were made with exceptional care. These men experimented with air by passing a strong electric spark through a confined volume of air, contained in a tube over mercury, thus causing some oxygen and nitrogen to unite, and forming an oxid of nitrogen. The latter was absorbed by a solution of potassium hydroxid, then more oxygen was introduced, and the sparking by electricity was continued, until finally only a small residue remained, which could not be made to combine with oxygen. The excess of oxygen was then absorbed, and the residual gas was placed in a Plücker tube under diminished pressure, and, while a current of electricity was passed through it, was examined by means of the spectroscope. The spectrum was different from that of any known gas. Other substances were brought in contact with this gas, but it did not unite with them, and the name "argon," which signifies "inactive," was given to the gas. This gas was also prepared

from air, after the oxygen had been removed, by passing it over red-hot magnesium, which took out the nitrogen and left the argon.

A little later, the element "helium" was found first in a mineral Clevite, and afterwards in the air. This element had previously been discovered in the atmosphere of the sun by the examination of sunlight with a spectroscope, and chemists were delighted to find that the gas which they obtained from certain minerals, and also from mineral springs, was the same as had previously been discovered in the sun. More recently the other gases, neon, krypton, xenon, were discovered. Since liquid air can now be made at a comparatively small expense in large quantities, these latter gases may be separated from it by "fractional distillation," and may thus be more thoroughly studied.

CONSTITUENTS OF THE AIR

The average composition of moist air by volume is as follows: —

	Parts per 1000
Oxygen	207.7
Nitrogen	773.5
Water	8.4
Argon	9.4
Carbon dioxid	.3 to .4
Nitric acid	Trace
Ammonia	Trace
Hydrogen sulfid	Trace
Sulfurous anhydrid	Trace
Helium	.001
Krypton	.001
Xenon	.0005
Hydrogen	.03
Neon	.01

* **Experiment 1.** To show the weight of air. Fill a glass tube about 900 mm. long, closed at one end, with clean, dry mercury and invert it over a vessel of mercury. Read the height of the column by means of a meter measure.

* This Experiment and any others marked *, if more convenient, may be performed by the instructor in the presence of the class.

* **Experiment 2.** Read a good barometer, and compare reading with that obtained in the tube.

* **Experiment 3.** To show the effect of moisture in air, or the vapor tension of water, add a small drop of water to the mercury, in Experiment 1 by putting it beneath the surface of the mercury in the tube, with a glass tube bent upward at the lower end. Record the difference of level.

Experiment 4. To prove the composition of air, melt some phosphorus [1] in one end of a 100 cc. eudiometer tube or plain glass tube, sealed at one end and tightly closed with a soft cork. The phosphorus may be melted by immersing the end of the tube containing the phosphorus in boiling water for a few minutes. Throw the phosphorus along the tube by a quick swing, and it should take fire. Immerse the corked end of the tube in a cylinder of water, remove the cork while still under water, and the water will rush in. When the contents of the tube has become of the same temperature as the air, read the level of the water inside the tube, first making it of the same height inside as outside, by lowering or raising the tube. Calculate the per cent of oxygen in the air.

AIR A MIXTURE

As previously stated, these gases, oxygen, nitrogen, etc., are **mechanically mixed** in the air. This may be proven as follows: —

1st, Because the air in different localities has different composition.

[1] In all experiments with phosphorus, observe the precaution never to touch it with the hands, as it ignites readily and produces severe burns.

2d, Because air dissolved in water is richer in oxygen than ordinary air.

3d, Because the mixture of oxygen and nitrogen in the proportion of air cannot be made to combine by a spark to form air.

4th, If liquid air is allowed to evaporate, the nitrogen goes off first, leaving nearly pure oxygen.

VITIATED AIR

Air is vitiated or rendered too impure for respiration from a variety of causes. Among these may be mentioned an increase in the amount of carbon dioxid, and a consequent decrease in the amount of oxygen; a lack of sufficient moisture, and an excess of moisture; by the presence of suspended impurities of a vegetable, animal, or mineral origin; by poisonous gases, from illuminating gas, sewers, or manufactories; by the presence of the impurities that are due to respiration, and by a mixture with ground air.

COMPOSITION OF AIR

The methods used for the **analysis** of air are usually volumetric. From a sanitary standpoint, the most practical thing is to determine the amount of some of the substances which are present in small quantity, but which are really of great hygienic importance.

It is assumed that we are familiar with the properties of **oxygen**, a gas that assists in combustion, causes a spark to burst into flame, and is absolutely necessary to respiration. The amount of oxygen found in the air in different localities varies, according to Bunsen, within narrow limits from 20.97 % to 20.84 %. These results were confirmed by Regnault, R. Angus Smith, Leeds, and others, who made

analyses of air from different parts of the world. In the crowded tenement districts the air has been found to contain as low as 20.60 % of oxygen.

The air as it leaves the lungs contains about 79 % of nitrogen and argon, and only 16 % of oxygen, for this air, instead of containing the normal amount of carbon dioxid, now contains about 4.4 %. The oxygen has been consumed in the vital processes. The human system is very susceptible to the disturbance of the normal proportions of the gases in the atmosphere, and this is one of the causes for discomfort in a crowded room.

Nitrogen, on the other hand, has properties that are, to some extent, opposed to those of oxygen. Nitrogen does not burn, does not support combustion, is not poisonous, and is, in fact, an inert gas. In combination, however, it is of special importance, as in nitrates, explosives, coloring matters, and alkaloids, as well as in some vegetable substances, and in nearly all animal tissues.

HUMIDITY OF AIR

Water in the air is necessary both for the growth of vegetable and animal life. The amount of vapor that air contains depends, of course, upon the temperature. The higher the temperature, the greater the amount of moisture the air will hold without precipitation. When air contains as much moisture as, at a given temperature, it is capable of holding, it is said to be saturated. Humidity has reference not to the actual *amount* of vapor present, but to the proportion which this bears to the possible maximum at that temperature. At 0° C., a cubic meter of air will hold only 4.87 g. of water; at 10° C., 9.92 g.; at 15° C., 12.76 g.; at 20° C., 17.16 g.; and at 32° C., 33.92 g.

If the air is absolutely dry, plants wither and die, and animals do not thrive, since they lose water too rapidly by evaporation. The amount of moisture in the air varies from $\frac{1}{66}$th to $\frac{1}{200}$th of the volume, and from 65 % to 75 % of saturation is regarded as most beneficial to health. If the humidity of the air is 90 % of saturation, and the temperature is 90° F., the conditions are almost unbearable, while at the same temperature, with 50 % of humidity, it is not uncomfortable. Air that is saturated with moisture does not permit the heat of the earth to radiate so rapidly. At night, as the air cools, we get a deposit of dew. It is well to remember that the "dew-point" or the temperature at which a deposit of moisture begins varies with the amount of moisture in the air. The earth cools more rapidly on clear nights, hence in cold, clear weather there is greater danger of frost. The amount of moisture thrown off from the lungs and skin is about one third of that taken in with the food. This would mean that from $1\frac{1}{2}$ to 2 lb. of water would be given off per capita every 24 hours. Moist climates are adapted to the treatment of certain diseases, while we are familiar with the action of dry air, such as that of Colorado, Arizona, and California, in the treatment of tuberculosis.

As air is essentially a mixture of one part of oxygen with four parts of nitrogen and a varying amount of water vapor, the weight of a liter of air would be equal to the sum of these constituents, and the way in which this weight will vary can be seen from the following figures: —

The weight of a liter of nitrogen is . . .	1.25 grams
The weight of a liter of oxygen is	1.43 "
The weight of a liter of water vapor is . .	.81 "

From the composition of the air above noted, a liter of dry air would contain practically

800 cc. of nitrogen weighing	1.000 g., and
200 cc. of oxygen weighing	.286 g.
Giving a total weight of air as	1.286 g.

Since water vapor is lighter than either nitrogen or oxygen, and since it displaces its own volume of these other gases, air containing water vapor will be lighter than an equal volume of dry air.

To illustrate: Suppose we have a sample of air containing 5 % of water vapor, then a liter of this air would contain

760 cc. of nitrogen weighing	.950 g., and
190 cc. of oxygen weighing	.272 g., and
50 cc. of water vapor weighing	.0405 g.
Total	1.2625 g.

Experiment 5. To show the presence of moisture in the air, fill a wide-mouthed flask of about 1 liter capacity with pounded ice or snow. Clean it thoroughly on the outside and wipe it dry. Suspend it in the room and notice after a short time the abundant deposit of moisture from the air.

Experiment 6. Suspend two thermometers that read alike side by side on the iron stand in the laboratory. Make a note of the readings. Fasten about the bulb of one of them by means of a rubber band a wad of cotton that has been thoroughly soaked in water, and place in a draught of air, or fan moderately. Note after a short time, when the mercury has become stationary, the difference in temperature of the two thermometers. Will there be this difference if the air is absolutely saturated with moisture?

CARBON DIOXID IN AIR

Carbon dioxid (CO_2) finds its way into the air: —

1. By combustion.
2. By respiration.
3. By the decay of vegetable matter.
4. By chemical action.
5. By volcanic action.
6. By the escape of ground air.

This gas is not poisonous, as this term is ordinarily used, but animals may be said to drown in carbon dioxid gas. The amount of this gas in 1000 parts of air varies in different places: for instance, in Munich it was found to be .051; in Scotland, .053; on London streets, .038; at Lake Geneva, .044. This is for the outdoor air. More recent investigations show that normal outdoor air contains between .03 and .04 parts of carbon dioxid. The air in crowded rooms is frequently extremely impure, as shown by the following analyses: [1] —

CARBON DIOXID IN CLOSED ROOMS

	Parts per 1000
A schoolroom in England contained	2.41
Sitting room in a private house	3.04
Public library	2.06
Courthouse gallery	2.90
Printing office	1.49
Tailor's workshop	3.06
Boot and shoe finisher's shop	5.28
Surrey Theater	2.18
Standard Theater	3.20
Girls' schoolroom	7.23
Schoolroom in New York City	2.80
Bedroom with closed windows	2.30
Average of 339 experiments in mines	7.85
Sleeping cabin of a canal boat	9.50

[1] Fox, "Sanitary Examination of Water, Air, and Food," p. 204.

It is no doubt true that the amount of carbon dioxid in the air has something to do with the disagreeable sensations experienced in a crowded room.

Some of these are: —
Headache
Stupor
Restlessness
Craving for excitement
Fainting
Nausea
Lowered Vitality.

According to the experiments by Drs. Billings, Mitchell, and Bergay, it is shown that the disagreeable effects produced upon the system by impure air are due to the following causes: the reduction in the amount of oxygen, the increase of carbon dioxid, excess of moisture, the high temperature, the dust and disagreeable odors, — in fact, to all these combined.

Some recent experiments on the effects of atmosphere deficient in oxygen on animals and on man [1] indicate that an atmosphere deficient in oxygen begins to affect man when the percentage of oxygen is about as low as that affecting canaries and mice. When the amount of oxygen is reduced to about 7 %, these animals show considerable distress and man is in danger of dying.

We know that considerable pure carbon dioxid is not especially injurious, as workmen in breweries and other manufactories are not affected by even a larger amount of carbon dioxid than is found in the air of a crowded room.

[1] Technical Paper 122, Dept. of Interior, Bureau of Mines.

According to the experiment of Cowles and Feilmann,[1] air that contains 14 % of carbon dioxid, and has remaining only 18.1 % of oxygen, will extinguish a candle flame. In the absence of carbon dioxid, air to which 22 % of nitrogen has been added will extinguish a candle flame. Expired air has about the same composition as that produced by the burning of a candle in an inclosed space until the candle goes out. As an atmosphere, even as impure as this, could be breathed without causing insensibility, the common test for the air of a well, by letting down a burning candle, is within the limit of safety.

For the **determination of carbon dioxid**, many forms of apparatus have been invented. Usually a measured amount of air is passed through a solution of barium hydroxid or calcium hydroxid, and the barium or calcium carbonate thus formed is filtered off and weighed. The reaction, where barium hydroxid is used, is as follows: —

$$Ba(OH)_2 + CO_2 = BaCO_3 + H_2O.$$

Experiment 7. To show the production of carbon dioxid by combustion, attach a funnel, by means of a tube bent twice at right angles, like an inverted "∩," to a Woulfe flask containing limewater. The end of the tube should be a little below the surface of the limewater. Through the other opening in the flask put a cork and glass tube, bent at a right angle, and aspirate air through the limewater. Note that the small amount of carbon dioxid in the air does not make the limewater turbid. Place a lighted candle beneath the funnel, and notice the formation of carbon dioxid. Write the equation for the combustion of the carbon of the candle, and for the precipitation in limewater.

Experiment 8. Repeat the above experiment with a *small* jet of illuminating gas under the funnel, and notice whether the limewater becomes as quickly turbid as with the candle.

[1] *Jour. Soc. Chem. Ind.*, Vol. 13, p. 1155; Vol. 14, p. 345.

Experiment 9. To show the presence of carbon dioxid in the breath, arrange an apparatus by the use of two Erlenmeyer flasks, or wide-mouthed bottles fitted with corks, each provided with two holes fitted with glass tubes, so arranged that air may be drawn in through limewater in one flask at each inspiration, and may be passed out through limewater in the other flask at each expiration. The tubes used for the inspiration and for the expiration of the air may be held side by side in the mouth by the use of rubber bands, although a better method is to use a Y tube to connect them. Notice that the limewater is turbid in one flask and not in the other. Why?

Experiment 10. To determine the amount of carbon dioxid gas in the air, use the *new* Wolpert apparatus, which depends on the amount of air that will be necessary to decolorize a slightly alkaline solution of phenolphthalein.

QUANTITATIVE DETERMINATIONS

* **Experiment 11.** Another method for the determination of the amount of carbon dioxid in the air is the following, known as Pettenkofer's method. Determine the strength of a solution of limewater or baryta water against a standard solution of oxalic acid, containing 2.84 grams of oxalic acid per liter, by placing 25 cc. of limewater in a porcelain dish, and running into this, through a graduated burette, enough oxalic acid to exactly neutralize it, using a strip of yellow turmeric paper as an outside indicator. This equation shows what takes place: —

$$H_2O_2C_2O_2 + Ca(OH)_2 = CaO_2C_2O_2 + 2\,H_2O.$$

Find the exact capacity of a glass-stoppered bottle of 4–6 liters capacity, and put a sample of the air to be tested in this bottle by means of a bicycle pump or a bellows. Measure into this bottle 50 cc. of limewater, shake, and set aside for 6 or 8 hours. Take out with a pipette 25 cc. of the limewater without shaking, so as to get as little calcium carbonate as possible, and titrate this with the standard oxalic acid; and the difference between

* See note on p. 5.

the amount used and the amount required to neutralize 25 cc. of the untreated limewater represents the effect due to the carbon dioxid gas in the air. The action of the carbon dioxid on the limewater is represented by the equation: —

$$CO_2 + Ca(OH)_2 = CaCO_3 + H_2O.$$

The oxalic acid used is of such strength that 1 cc. corresponds to 0.5 cc. of carbon dioxid gas. Subtract 50 cc. from the capacity of the bottle for the space occupied by the limewater. Calculate the parts of carbon dioxid per 10,000 parts of air. This may be reduced to standard conditions of temperature and pressure by the usual methods. (See "Public Health Laboratory Work," Kenwood, p. 194.)

An example of the calculation is as follows: Suppose it required 30 cc. of oxalic acid solution to neutralize 25 cc. of limewater, and the 25 cc. of limewater from the bottle of air is neutralized by, say, 27 cc. of the oxalic acid solution. This means that the carbon dioxid in the air was equivalent to 3 cc. of oxalic acid solution. 1 cc. of this solution = 0.5 of carbon dioxid, then 3 cc. = 1.5 cc., which multiplied by 2 for the other 25 cc. of limewater in the bottle gives 3 cc. of carbon dioxid. If the capacity of the bottle was 4000 cc., subtract 50 cc. from this = 3950 = volume of the air taken. Hence we calculate .0759% of carbon dioxid in the air, or 7.59 parts in 10,000 parts of air.

The American Public Health Association's Committee on Standard Methods for the Examination of Air [1] recommend the use of a modified form of the Petterson-Palmquist apparatus, which depends on the principle of treating a measured quantity of air with potassium hydroxid, and again measuring it, thus giving the carbon dioxid by difference. Haldane's apparatus is quite similar and gives excellent results, in the hands of an experienced operator, in about five minutes.

[1] *Am. Jour. Pub. Health*, Vol. III, p. 81; Vol. VII, p. 66.

CARBON MONOXID IN AIR

Carbon monoxid (CO) is sometimes found in the air of inhabited rooms, on account of insufficient ventilation or leaky joints in furnaces. Red-hot cast iron will also transmit the gas. As it is extremely poisonous, — less than one half of one per cent in air being fatal to human life, — it is of the utmost importance that it be excluded from the air of our dwellings. Fortunately, although carbon monoxid itself has no odor, it is usually mixed with some other gas that has a decided odor. In coal gas it is mixed with the sulfur compounds which are so readily detected by smell, and in escaping furnace gases it is usually accompanied by sulfur dioxid, which has the familiar odor of a burning match. When formed by burning charcoal, there is scarcely a perceptible odor. (See Ventilation, p. 45.)

OTHER GASES IN AIR

Nitric acid in the air is largely a result of the oxidation of the ammonia. Some nitrogen oxids are formed from free nitrogen by the lightning flashes in the air. The nitric acid, when washed into the soil by the rains, is of great value as a fertilizer for growing plants.

Ammonia is formed partly by the decay of vegetable and animal matter in the soil and partly by other chemical processes. Ammonia would naturally unite with carbon dioxid, making ammonium carbonate, or with the nitric acid, making ammonium nitrate; and both the acid and the base in this latter salt are useful when washed down by the rain, in enriching the soil. The amount of ammonia varies from 0.1 to 100 volumes in a million volumes of air.

Hydrogen sulfid (H_2S) will not ordinarily be found in pure air, but in cities, where there is decomposition of organic matter and sewer gas, it may be frequently detected by its disagreeable odor. Sulfurous anhydrid is not a constituent of the pure air of the country, but where soft coal is burned, or where there are manufactories operating, this gas will be found. Sulfur dioxid is quite noticeable in the vicinity of chemical works, especially where zinc, lead, and copper ores are smelted. An extremely small quantity of the gas in the air is fatal to vegetable life, so that trees and shrubs in the vicinity of smelters and chemical works, especially on the side toward which the prevalent wind carries the fumes, are killed.

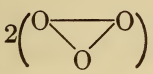
Hydrogen peroxid (H_2O_2) is a powerful oxidizing agent which is present in small quantities in the air and in rain and snow water. It is probable that some of the effects often ascribed to ozone are really due to hydrogen peroxid, as it has similar oxidizing action. A 3 % solution of hydrogen peroxid in water is the well-known commercial disinfectant.

OZONE

There is an interesting form of oxygen known as **ozone.** It was noticed many years ago that a peculiar smell accompanied a thunderstorm, and this as well as the lightning was ascribed to evil spirits. As early as 1785 Van Marum noticed a peculiar odor in the vicinity of an electrical machine, and recognized that it was the same as that accompanying lightning discharges. It was not till 1840, however, that Schönbein, a Swiss chemist, discovered ozone, and showed that electricity changes oxygen to ozone.

In addition to the production of ozone by electrical dis-

charges, it is formed in many other ways, as by the slow oxidation of phosphorus, by the partial combustion of ether, and by the action of sulfuric acid on potassium permanganate or on barium dioxid. Ozone slowly changes back to oxygen at 100° C. and rapidly at 300° C. It has been shown that ozone can be smelled if present in the proportion of one volume of ozone to $2\frac{1}{2}$ million volumes of air. When a known volume of ozone is changed back to oxygen, there is an increase in volume. This is due to the fact that a molecule of ozone contains three atoms and a molecule of oxygen, two atoms, hence :—



Ozone is a very powerful oxidizing agent and unless greatly diluted has an irritating action on the mucous membrane. Since many coloring substances are destroyed by ozone, it is often used as a bleaching agent. It is also used for the sterilization of water and the purification of air on a commercial scale. Air is thus purified from traces of organic matter by oxidation. There is considerable controversy and authorities differ as to whether the bacteria in the air are destroyed by ozone. The air of the underground railway in London is purified by blowing in ozone with the fresh air, and the air of hospitals is often purified in the same way.

It was for a long time supposed that the test with " ozone paper " was a positive proof that ozone existed in the air, but as other substances, such as some of the oxids of nitrogen, color ozone paper in a similar way, there is still some doubt as to whether it exists in appreciable quantities in the atmosphere.

Experiment 12. To make "ozone paper," mix about 5 g. of starch with 20 cc. of cold distilled water. Pour this into a beaker containing 100 cc. of boiling water, in which has been dissolved about a gram of potassium iodid. Heat the mixture for a moment. Soak strips of white filter paper in this solution and allow them to dry in pure air. The paper turns blue in the presence of ozone.

Experiment 13. To make ozone, turn a static electrical machine and test the air in the vicinity by means of moist ozone paper.

Experiment 14. Heat a large glass rod in a Bunsen burner. Pour a few drops of ether into a medium-sized beaker and move the rod around in the vapor of ether. Test this vapor for ozone, which with other products is probably present.

Experiment 15. Cut some phosphorus in thin slices *under water*, and place them in a cylinder with a little warm, not hot, water in the bottom, but not enough to cover the phosphorus. Suspend some pieces of moist ozone paper in the jar and place a cover over it. After a time the paper will turn blue, showing the presence of ozone.

SUBSTANCES IN SUSPENSION IN THE AIR

Although the air is apparently clear and transparent, yet we have only to admit a ray of sunlight into a room to see the **dust** which is in the air. "Minute particles of anything and everything that exists upon the earth are liable to be mingled in the air that rests on it. These suspended matters are furnished by the animal, vegetable, and mineral kingdoms." [1] We get, in the animal kingdom, the débris of little insects suspended in the atmosphere — eggs and other substances. From the vegetable kingdom we get spores of fungi, bacteria, pollen of plants, seeds of all kinds,

[1] Fox, "Water, Air, and Food," p. 264.

particles of straw, etc. From the soil, the dust of inorganic composition, such as sand, iron oxid, lime, mud from volcanoes, particles of carbon, sulfur, and, in the vicinity of the ocean, sodium chlorid and other minerals carried long distances by the wind.

EXAMINATION OF AIR

The air of sick rooms, hospitals, and prisons has been carefully examined, and a microscopic study has been made of the dust collected. It has been found to contain a variety of organic matter. The first method of examination is by passing a known quantity of air through a tube closely packed with sterilized cotton, and then washing the cotton and examining the wash water. By this means we can arrive at the number of spores per liter of air. A known volume of air may be drawn through sand or sugar and sterilized liquid gelatin added to this, and finally the number of colonies in the gelatin may be counted. A more convenient method, however, is what is known as the plating method, in which we pour into a series of shallow glass vessels, called Petri dishes, a nutrient medium which becomes solid on cooling. To this the dust particles readily adhere. This gives a moist, sticky surface, which can be easily protected by tightly fitting covers. When we desire to examine the air in any locality, one of these vessels is opened and exposed to the air for a specified time, say 25 min. In this way it is possible to compare the air in different localities. By counting colonies, each one of which presumably consists of the offspring of a single germ, the following numbers of bacteria were found under different conditions in New York City: —

Central Park, dust blowing	49
Union Square	214
In a private house	34
Dry goods store	199
Broadway and 35th St.	941
When the street was being cleaned	5810
In a house called clean	180
In a filthy house	900
In a dirty schoolroom with natural ventilation	2000
Average in hospitals and dispensatories	127

There are, in fact, more living microörganisms in the air than the above results would indicate, for many germs do not find in the nutrient medium conditions favorable to development. It is understood that these organisms are of widely different character, although they are generally either molds, yeasts, or bacteria. It is estimated that in the open country in a cubic inch of air there may be 2000 dust particles, 3,000,000 in the air of city streets, and 30,000,000 in that of inhabited rooms.[1] While microorganisms are very abundant in the air of towns, there are hardly any at great heights and at sea. Pasteur exposed a large number of flasks of broth at an altitude of 6000 feet, and obtained a growth in but one. Tyndall exposed twenty-seven flasks at 8000 feet and got no growth whatever. Dr. Fisher has shown that on the ocean 120 miles from land the air is usually free from organisms and that at a lesser distance — 90 miles, for example — it contains but few.[2]

Some recent experiments (1914) on city air have been made by M. C. Whipple.[3] He secured the samples of air for bacterial and dust examination by drawing air by means of a small fan motor through an adaptor tube

[1] *Nature*, Vol. 31, p. 265; Vol. 41, p. 394.
[2] Harrington, "Practical Hygiene," p. 233.
[3] *Am. Jour. Pub. Health*, Vol. V, p. 725.

containing a layer of sand. Later this was washed out of the tube by the use of sterile water, and for the collection of the dust particles a half inch layer of resorcinol crystals was employed. These crystals are then dissolved in clear water, and the particles remaining are examined and counted under the microscope with a 16 mm. objective. It was found that there were 18,000 particles per cubic foot in air over Long Island Sound, 27,000 at the 57th story of the Woolworth Building in New York City, at a time when the street air showed 221,000 particles. In all cases the air of schoolrooms contained more particles of dust and more bacteria than the outside air. In the elevated railway cars in Boston, the number of dust particles was often very high, being in one instance 3,415,000 per cubic foot.

EFFECTS OF DUST

Dust, however, is of great importance on account of its influence upon the precipitation of rain, upon clouds and fog.

There are certain diseases, such as consumption, diphtheria, smallpox, yellow fever, Asiatic cholera, scarlatina, measles, etc., which are called infectious, and which are often propagated by bacteria in the air. Much attention has been paid to the propagation of consumption, and the *Bacillus tuberculosis* has been quite thoroughly studied. It is stated that in Europe about a million persons die annually from consumption, and one tenth of all the people of the civilized world fall victims to this disease. Dr. Francine (*J. Am. Med. Assn.*, 1905) says that 110,000 persons die every year in America from consumption. This is a disease in which the germs from the dry sputa are carried in the air, lodged

in the air passages, and, if they find the system in the right condition, they commence to grow and carry on their deadly work.

On account of a better understanding of the disease, and more rational methods of treatment, and especially because of the great effort that has been made to disseminate information in regard to the cause and cure of tuberculosis, and the better housing and sleeping habits of the people, and the wide-extended use of the sleeping-porch, the mortality from tuberculosis has been much decreased within the last 25 years. Recent figures show that the death rate from tuberculosis of the lungs in the registration area of the United States has diminished from 175 per 100,000 population in 1900 to 125 in 1914. In American cities the death rate from tuberculosis has diminished since 1870 from 340 per 100,000 to 150 in 1914.

VACUUM CLEANERS

Too much can hardly be said in favor of the modern method of removing dust and dirt by the use of vacuum cleaners. The use of these machines, which need not be elaborate or expensive, is one of the most important steps that has been made for years in the direction of keeping the air of our dwellings free from dust. Instead of stirring up the dust by means of a broom and duster, to have it settle again upon the floor and furniture, the vacuum cleaner removes it from the room.

ARSENIC IN WALL PAPER

A few years ago there was a great outcry against arsenic in wall paper, and it was said that the dust of many rooms, in which the walls were hung with ordinary paper, was

laden with arsenic. An excellent article on this subject appeared in the Report of the Massachusetts Board of Health for 1883. The agitation of those times no doubt caused the manufacturers to substitute other coloring matters in the place of arsenical, so that at the present time it is very unusual to find a wall paper that contains arsenic.

Experiment 16. To test for arsenic in paper[1] or in fabrics, cut the paper or green cloth into shreds, and boil this in a test tube, half full of water. Add to this about 10% of strong hydrochloric acid and a very small piece of bright copper foil. Boil the liquid for at least five minutes and notice if there is any dark coloration on the copper. When no coloration appears, arsenic is absent. If there is a coloration or deposit, remove the piece of copper carefully and wash thoroughly. Dry it on a piece of filter paper over a lamp and then place it in a matrass (a small glass tube closed at one end) and heat cautiously. If arsenic is present, there will be a sublimate of crystals of arsenious oxid (As_2O_3) on the inside of the tube. Examine these crystals with a lens and notice also if they reflect light or show triangular faces.

INJURIOUS TRADES

There are many trades in which the health of the workmen suffers from dust or injurious gases. Dr. Hirt has studied the effect of various trades on the health of the workmen in Germany. He made a particular study of consumption among the workmen, and gives the following as a list of the most injurious trades: flint cutting, needle and file making, lithographing, binding, brush making, stone cutting, grindstone cutting, type founding, cigar making, molding, glass working, dyeing, and weaving. The sharp mineral dust is by far the most

[1] Arsenical paper may be prepared by soaking filter paper in a solution of sodium arsenite or in Paris green, suspended in water.

injurious. The worst vegetable dust is cotton fiber, and this produces great mortality, especially among women. The mortality is probably increased on account of the high temperature and lack of ventilation in the manufactories where they are obliged to work.

GROUND AIR

Air is contained in the ground sometimes to a depth of 20 feet. It is forced into the ground both by its weight and by the pressure of strong winds. Pettenkofer found in 1870 that the air contained in the ground is not as pure as ordinary air. A comparison of dry ground air with ordinary dry air is given by Price.[1]

AVERAGE COMPOSITION OF ATMOSPHERIC AIR IN 100 VOLUMES

Nitrogen	79.00%
Oxygen	20.96%
Carbon dioxid	.04%

AVERAGE COMPOSITION OF GROUND AIR

Nitrogen	79.00%
Oxygen	10.35%
Carbon dioxid	9.74%

The excess of carbon dioxid is due to decay of organic matter that has taken place in the soil, and the decrease in oxygen is due to the fact that it has been used up by the bacteria and in various processes of oxidation. This air also contains a large number of bacteria, and other organic forms of life. When we remember that a cubic centimeter of earth contains from 200,000 to 1,000,000 bacteria, the opportunities for contamination of the ground air are apparent. The air of virgin soil is usually more free

[1] "Handbook of Sanitation," p. 3.

from organic impurities than the air from the ground of thickly populated districts, and the difference can be readily understood when we consider the material which is liable to collect in or filter through the soil of a city. Fatal results have sometimes followed the breathing of air poisoned by the decay of organic matter. Sir Henry Thompson states that gravediggers have died while digging in the region of vaults and cemeteries.[1] If houses are built upon the so-called " made " land that has been filled in with all sorts of refuse from the city and from manufactories, the air that comes into the rooms is liable to be contaminated and to be deficient in oxygen. On account of the vitiation of air by decaying organic matter, in large cities, cremation has been quite extensively advocated and is no doubt an excellent method for the disposal of garbage and dead bodies.

OFFENSIVE GASES

In the ordinary apartment there is little danger of injury from poisonous gases. In the centers of trade the gases from some manufactories would be offensive, if they were taken into the lungs, but they are rapidly diffused through the atmosphere. Even sewer gas, which is usually considered so dangerous, has been shown frequently to contain a less number of microörganisms than the outside air. This gas is, of course, disagreeable, often lacking in oxygen, and should by no means be allowed to escape into a dwelling.

[1] "Cremation," R. E. Williams, p. 44.

CHAPTER II

FUELS

HISTORY

As previously stated, fire was regarded by the ancients as one of the elements and a gift of the gods. Stahl, a German chemist, in 1697 advanced the theory that when anything is burned a volatile substance called "phlogiston," which was contained in the combustible material, escaped. It was only after the discovery of oxygen, in the latter half of the eighteenth century, that the true theory of combustion began to be understood. Ordinary combustion is simply a combination of the combustible part of the fuel with the oxygen of the air, leaving nitrogen and the other gases unchanged. By this burning of the fuel an oxid is formed; if carbon burns, it is the oxid of carbon known as carbon dioxid; if hydrogen burns, it is the oxid of hydrogen known as water.

In the production of heat for ordinary purposes, such fuels as wood, charcoal, peat, lignite, bituminous coal, cannel coal, semianthracite, anthracite, coal gas, and natural gas are used. Wood spirit, denatured alcohol, common alcohol, gasoline, and kerosene find a limited use; and electricity may be used for heating under special conditions.

The combustible elements in these fuels are carbon and hydrogen, the former burning with scarcely any visible

flame, and the latter also burning with a colorless flame. The calorific power of fuels, that is, the quantity of heat evolved by burning one gram in oxygen, differs greatly.

The unit, in terms of which quantities of heat are measured, is the calorie. A calorie is the quantity of heat required to raise the temperature of one gram of water one degree centigrade. Since this quantity varies with the temperature of the water, it is usual to specify that the water shall be at 15° C. and be raised to 16° C.

Heat values of combustibles are often given in terms of British Thermal Units (B.T.U.) per pound of fuel, or in the case of gases per cubic foot. A B.T.U. is the amount of heat required to raise one pound of water one degree F., usually from 59°–60°. The following are some of the more common values obtained: —

Solid and Liquid Fuels [1]

Fuel	Calories per Kilo	Btu per Lb.	(0° C.; 760 Mm.) Btu per Cu. Ft.
Carbon to CO_2	8,140	14,650	
Lignites	4,000 to 8,000	7,200 to 14,400	
Peat (average)	4,500	8,100	
Wood	3,000 to 6,000	5,400 to 10,800	
Oven cokes	8,000	14,000	
Gas cokes	7,800	14,000	
Oil (petroleum)	10,000	18,000	

[1] "Calorific Power of Fuels," Poole, p. 210 *et seq.*

GASEOUS FUELS [1]

FUEL	CALORIES PER KILO	BTU PER LB.	(0° C.; 760 MM.) BTU PER CU. FT.
Hydrogen	34,500	62,100	348
Carbon monoxid	2,487	4,476	349
Methane (Marsh gas)	13,245	23,851	1065
Acetylene	11,925	21,465	1555
Benzene (C_6H_6)	10,250	18,450	4010
Natural gas (average value)			1000
Artificial gas (average value)			600
Pintsch gas			1320
Water gas			300

As many combustibles contain some oxygen in addition to the carbon and hydrogen, in order to find the actual amount of heat developed, we estimate what would be produced from the combustion of the carbon, and of so much hydrogen as is in excess of that necessary to form water with the oxygen present in the fuel. In estimating the available heat produced, we must deduct from the total calorific power the amount of heat necessary to convert into steam all the water formed by the combination of the hydrogen, and all the water originally present in the fuel.

When the carbon is burned, the sole product of the combustion is carbon dioxid, thus, $C + O_2 = CO_2$; but if the combustion is incomplete from lack of sufficient air, the combustion would be represented by the equation, $2\,C + O_2 = 2\,CO$, in which the poisonous gas, carbon monoxid, is formed at the same time as the carbon dioxid. It will also be seen from the above table that much less heat results from the burning to carbon monoxid than when the

[1] Thompson's "Thermochemie Untersuchungen."

carbon burns completely to carbon dioxid. Smoke consists largely of unburned carbon, which might have been burned completely to carbon dioxid if the conditions for combustion had been better.

In the burning of hydrogen, nothing but water, in the form of steam, is produced, thus, $2\,H_2 + O_2 = 2\,H_2O$. In addition to the above products there are some others that are incidental, and due to impurities in the combustibles.

The original basis of the ordinary fuels is cellulose $(C_6H_{10}O_5)_n$, which is found in a very pure form in clean cotton and in pure filter paper. It is believed by geologists that not only peat, but also the different kinds of coal, came originally from vegetable material. In the case of peat the amount of oxygen and hydrogen have not been so completely eliminated by the combined action of heat and pressure in the earth, as in the case of the soft coals and anthracite.

WOOD AS FUEL

If a fuel is porous, like wood, so that the air can penetrate into the interior, it will be readily ignited and burn quite freely. The ordinary practice of piling the wood loosely to build a fire is, of course, in accordance with this principle. If the fuel contains considerable hydrogen, especially when in the proportion to unite with oxygen, as in the case with wood, it is free burning. When but little luminous gas can be formed, as in the burning of charcoal, coke, or anthracite, the heat is more intense and concentrated at a point near the burning material. Other fuels, such as wood, soft coal, petroleum, etc., burn with a long, smoky flame, and the heat will be distributed over a larger flue surface.

The experience of foresters, both in this country and

in Europe, has shown that to be fit for fuel and economical for use, the softer woods must grow from twenty to thirty years and the harder woods from fifty to one hundred and twenty years. In many parts of Europe the government requires that the forests be renewed as often as they are cut, and only in this way is it possible to keep the supply of fuel and timber intact. The preservation of forests also tends to keep the moisture in the soil, so that the streams shall not dry up in summer and there will not be the liability to sudden floods that there is in regions from which the timber has been cut.

There is more water in wood that is cut in the spring than if it is cut in January, and there is more in the young twigs and stems than in older wood. Different varieties of freshly cut wood contain the following per cent of water: —

Willow	26.0%	Aspen	43.7%
Sycamore	27.0%	Elm	44.5%
Birch	30.8%	Fir	45.2%
Oak	34.7%	Larch	48.6%
Pine	39.7%	White Poplar	50.6%
Beech	39.7%		

One and a half to two years after being cut wood gets as dry as it can by simple exposure to the air, and it is called "seasoned" or "air dried," but it still contains from 20% to 25% of moisture.

Wood several years old, kept in a warm room, may still retain 17% of moisture. Wood may be kiln-dried, and in this process will lose from 16% to 20% of moisture. If the air is expelled from wood, it is sensibly heavier than water, and the specific gravity is from 1.30 to 1.50. On account of being heavier than water, "water-soaked" wood, or that in which all the air has been replaced by water, will of course sink to the bottom of a stream.

The amount of moisture in wood is of great importance, because of the large amount of heat that is used up in its evaporation when burning; and so it goes without saying that dry wood is more economical than green wood. Resinous woods, such as fir, spruce, and pine, have an increased heating value on account of the pitch and resinous gums which they contain.

The best woods to use for fuel are the hard woods such as hickory, oak, maple, and beech. These burn slowly and have great heating value.

The amount of ash in wood differs greatly as it is made from old or young wood and from the whole wood or the bark. Willow wood contains 2% of ash; oak, 1.65%; beech, 1.06%; Scotch fir, 1.04%; birch, 0.85%. This ash consists essentially of sodium and potassium carbonates, calcium and magnesium carbonates, with some phosphates, sulfates, and silica (see Soap, p. 128).

CHARCOAL

When wood is heated in a limited supply of air, a kind of distillation takes place, and the residue that is left is called charcoal. The ordinary method of charcoal making has been to pile the wood and cover with turf or soil, and then apply a flame to the center of the pile and allow a little air to enter the bottom so that the combustion shall go on slowly. This process requires several weeks, and no attempt is made to utilize any of the valuable constituents in the smoke and gas given off.

Charring in kilns has more recently been resorted to, and here the products of combustion are utilized. The wood is placed in a brick kiln, which is heated by the combustible gases given off from other furnaces of the same battery. The smoke and other products of combustion are drawn

out of the kiln by fans, through a series of condensers, where the wood alcohol, tar, and crude acetic acid are deposited, and afterward purified for the market. About 27 % of charcoal is the yield by this process, while only 20 % is produced by the charcoal pit process.

PEAT

This fuel is very slowly formed, especially in shallow pools, by the decomposition of vegetable matter. The peasants in Great Britain, Northern Germany, Holland, and some other countries cut the peat or "turf," as it is sometimes called, into cubical blocks and pile it on platforms to dry. As it often contains as much as 45 % of water, it is important that the drying should be thoroughly done, or in burning but little heat will be obtained. It is, of course, a cheap fuel and burns with a smoky flame.

A peat bog is composed of the various mosses and sedges that grow so readily in damp ground and die at the end of the season, to be succeeded by similar vegetation the next season. Sometimes trunks of trees are found in it and even animal remains. Peat contains about 16 % of water and 41 % of fixed carbon.

It is estimated that there are in Great Britain 6,000,000 acres of peat swamps, and that each acre would yield 1000 tons of peat charcoal. In Ireland one seventh of the whole island, or 2,830,000 acres, is peat bog. The value of peat depends on its dryness, density, and firmness. Peat leaves from 8 % to 12 % of ash.

COAL

Lignite or brown coal is intermediate between peat and ordinary soft coal in composition, and is of more recent for-

mation than the latter. Although it burns freely, it contains from 15% to 20% of moisture, and leaves quite a large amount of ash.

Cannel coal is a peculiar variety of coal, having a conchoidal fracture like broken glass, and only a slight luster. The name comes from the Scotch pronunciation of the word "candle," and refers to the fact that splinters of this coal will burn like a candle. Cannel coal is especially valuable for making illuminating gas, as it yields a large quantity per ton.

Bituminous coal is very widely distributed in most countries of the world. Some of these coals burn with a smoky flame, and "cake," or form a coke which is hard and seems to fuse together, while others are "non-caking," and burn freely, with little smoke, to an ash. The latter are well adapted for domestic use. In the use of an oven that is heated with a fire on the outside, the former is a cheap and satisfactory fuel, except for the abundance of smoke which it gives off.

Semibituminous coals are found in several localities, but particularly from Pennsylvania across the southern boundary of Virginia into Tennessee. The volatile matter ranges from 12% to 25%, and this combustible portion is quite uniform in composition.

The **semianthracite coals**, like the Eureka and Ouita of Arkansas, burn freely, with but little flame, and show a tendency to decrepitate and fall through the grate.

Anthracite coal occurs only in a few localities, but sometimes in veins forty feet in thickness. It has a high luster, and a specific gravity of about 1.75. It burns with little flame and smoke, and is admirably adapted for domestic use, as the heat is concentrated and intense directly over the fire rather than distributed through a

long flue as when soft coal burns. When a naked fire is used for baking, as in a large cracker bakery, anthracite or coke is a very satisfactory fuel.

Coke, the material left in the retort after gas has been made from soft coal (see p. 62), is quite a bulky fuel, and leaves considerable ash. It is also made in "bee hive" coke ovens, and the distillation products are allowed to escape. "By-product" coke ovens are coming into use to save the very valuable substances such as ammonia and coal-tar products found in the gases and smoke.

Briquettes are being used to save the waste both in this country and abroad. They are made by compressing with tarry matter, in a suitable mold, the powdered coal that is formed in preparing the product for market.

Petroleum coke is left in the retorts after all the volatile constituents have been driven off from the oil. It is a clean, porous product and an excellent fuel for domestic purposes.

Analysis of Various Coals

	Water	Volatile and Combustible Matters	Fixed Carbon	Ash
Lignite	18.00	20.90	50.90	10.20
Semibituminous, Pa.[1]	0.81	21.10	74.08	3.36
Bituminous, Pa.[1]	1.97	38.60	54.15	4.10
Cannel	undet.	37.20	61.60	1.20
Cañon City, Colo.	6.47	38.82	49.10	5.61
Semianthracite, Ark.	1.11	12.73	77.62	8.56
Anthracite [1]	3.09	4.28	83.81	8.18

The greater the amount of moisture the less valuable the coal, as in the case of wood. The "volatile and com-

[1] Trans. A. I. M. E.

bustible" matter referred to in the table is that which goes off when the coal is heated in a closed vessel. It is this which gives the smoky flame to bituminous coal. Fixed carbon is the coke, which finally burns with little flame and leaves a residue of ash. It will be noticed that there is a regular decrease in volatile matter, from the bituminous coal to the anthracite, and a corresponding increase in fixed carbon.

COAL AND COKE

Experiment 17. Heat to a high temperature over a blast lamp as long as any smoke is given off about 2 g. of pulverized "coking" bituminous coal in a platinum or porcelain crucible closely covered. When the cover is removed, the mass of coke will be found in the crucible. This, less the ash which would remain on complete combustion in the air, constitutes the "fixed carbon" referred to above.

In many localities where there is no local supply of coal, there is a direct relation between the retail cost of different kinds of coal and the amount of fixed carbon which they contain, — the greater the per cent of fixed carbon, the higher the price.

Experiment 18. Compare the retail price of different kinds of coal, as anthracite, semianthracite, bituminous, etc., and the composition as given on page 34.

GAS AS FUEL

Natural and artificial gas are both important fuels, even for domestic use. Natural gas has been in use on a small scale for a number of years, but it was not until about 1880 that it became of commercial importance in the United States. It is now obtained in quite large quantities in Pennsylvania, New York, West Virginia, Ohio, Indiana, Kentucky, Texas, and Kansas. The method of boring the

well is to use what is called a churn drill, which pulverizes the rock, and the borings may then be washed out with a stream of water.

The hole, which is from 4 to 6 in. in diameter, is usually cased with iron pipe as the drilling progresses, but the casing is smaller nearer the bottom. The depth is usually from 300 to 1600 feet. The gas occurs in what is called a "gas sand," which is often quite thick. The pressure of the gas is frequently from 300 to 400 lb. per square inch, so that it is with great difficulty held in check. The gas is often conveyed in pipes for hundreds of miles, in which case powerful pumps are used to force the gas through the pipes and finally, by regulators, the pressure is reduced for domestic consumption so that it shall be burned at from 4 to 12 inches of water pressure.

A cheap fuel gas can be made in some sections at a low price, and will, it is hoped, supersede the use of coal for cooking and heating in large towns and cities where natural gas cannot be obtained. The advantages of burning gas over any other fuel are obvious, for it is immediately available to warm a room or cook a meal, and there is no waste of fuel, when the occasion for its use is past. There is no dust, ashes, or smoke, and the products of combustion can be carried out of the room by a very small pipe. These products should, however, **always be removed**, for, if allowed to accumulate, the carbon dioxid and other gases make the air of the room decidedly impure. The gas stove does not heat the room unnecessarily as does a coal stove, and gas is a perfectly safe fuel, which is more than can be said of gasoline as ordinarily used.

The **burners** used in heating by gas are all made on the principle of the Bunsen burner. The proper amount of air is allowed to enter at the bottom of the tube or, in the

large burners, through the "mixer." The burner that is put into a cook stove, for instance, can be made of a piece of two-inch gas pipe capped at one end and having three rows of small holes drilled in the top from one end to a point near the other. The "mixer" is screwed on at the end through which the gas is admitted. There is little danger in the use of natural gas if ordinary precautions are taken. There is, of course, a possibility that the pressure may change so that the gas may go out at night, but this is not often the case with the present methods of regulating the supply. It is true that there are some cases of suffocation from the careless use of natural gas, but it is not as poisonous as coal gas or "water gas" (see Lighting, p. 63).

The **composition** of **natural gas** from different localities is as follows: —

	Ohio	Indiana	Kansas[1]	Russia
Carbon dioxid	.3	.25	.44	.95
Carbon monoxid	.5	.45	.33	—
Marsh gas	92.6	92.67	95.28	92.49
Nitrogen	3.5	3.53	3.28	2.13
Oxygen	.3	.35	—	—
Hydrogen[2]	2.3	2.35	—	.94
Hydrogen sulfid	.2	.15	—	—
Olefiant gas, etc.	.3	.25	.67	4.11

The preparation and properties of illuminating gas are discussed under Lighting, p. 62.

Gasoline, one of the products from the distillation of petroleum, which is so extensively used as a fuel for cook-

[1] This gas has a "B. T. U." (British Thermal Unit) value of 920, as ordinarily computed.

[2] By recent methods of analysis, natural gas is usually found to be practically free from hydrogen.

ing in some localities, is burned in stoves so constructed that the liquid is converted into vapor by the heat of the burner before it is burned, and it is also mixed with sufficient air so as to burn completely with a blue flame, which does not deposit soot on the cooking utensils.

The chief danger in the use of gasoline is due to the fact that it gives off a volatile vapor, even at ordinary temperature. The vapor of gasoline is not only extremely combustible, but when mixed with a certain proportion of air it is highly explosive. Gasoline stoves are usually so constructed that the tank which holds the liquid is at some distance from the flame and it should **never** be filled without first extinguishing the flame.

Kerosene is often used as a fuel for heating and cooking. As at present burned in stoves of special construction it is very satisfactory. There is danger of smoking unless the wick is carefully trimmed. The products of combustion should always be carried away by a suitable flue, as they are both disagreeable and injurious to health.

Wood alcohol, known also as methyl alcohol, is often used for heating chafing dishes, coffee percolators, etc. It has three fourths the heating value of ordinary alcohol or "grain spirits." Grain alcohol which is " denatured " by adding to it some substance that renders it unpalatable, is an excellent fuel to use for small fires.

CHAPTER III

HEATING AND VENTILATION

HEATING

THESE two subjects are so intimately associated that one cannot be considered without the other, and one system should be installed at the same time as the other.

The common methods of heating are through —

(1) Direct radiation.
(2) Indirect radiation.
(3) Direct-indirect radiation.

The means of obtaining the heat are : —

By the fireplace or open grate.
By stoves.
By hot-air furnaces.
By steam with direct radiation.
By steam with indirect radiation.
By hot water with direct radiation.
By hot water with indirect radiation.
By electricity.

Direct radiation includes the use of a fireplace or open grate, which, however satisfactory it is in the way of ventilation and for imparting cheerfulness to a room, is not an economical method of heating, because it wastes from 75 % to 90 % of the fuel. The fireplace, where only the radiant heat was utilized, was the primitive method of heating

dwellings when fuel was not expensive. Many devices have been proposed for making the fireplace more efficient. Among them may be mentioned the ventilating grate, in which air is brought from outside and heated by passing back of the fire and then comes into the room through gratings above the fireplace. The Franklin stove, invented by Benjamin Franklin when placed partly within the room, is an illustration of heating by a combination of the radiation and convection methods. One of the chief reasons why people take cold so easily is that they work, eat, and sleep in rooms that are heated to a high temperature, with little moisture, and where no attention is paid to ventilation. The fireplace, which was universally used less than seventy-five years ago, furnished pure air, although the heat of the room was badly distributed.

Under the head of direct radiation may also be included the heating by **stoves**, or by pipes or radiators carrying steam or hot water. When the room is heated by a stove, as air is necessary for the combustion of the fuel, and therefore is removed from the room through the chimney, an equivalent amount must enter the rooms through the cracks around the doors and windows. This affords some ventilation, but not enough for rooms in which a number of persons are assembled. Direct radiation systems are cheaper in construction and, with the exception of the open grate or fireplace, do not use as much fuel as indirect systems.

When rooms are heated by a **stove**, there is no reason why air cannot be brought in from the outside beneath the stove, and pass over it to become heated, and then into the room. By this means fresh air will find its way into a room, and there is little difficulty in removing air from a room, especially if it is warm or under a little pressure.

In the use of the stove for heating, it should be large enough to thoroughly heat the room, even in the coldest weather, without running it at its fullest heating capacity, for it is not economy to heat a room with a small radiating surface. The air of the room that is in contact with this surface becomes overheated. Stoves heat a room largely by convection, that is, by heating the air that is directly in contact with the stove, and when this becomes heated, it rises and gives place to colder air.

The openings at the bottom of a stove or furnace should be so arranged as to completely shut out the air if necessary, and thus control the fire. This is much safer than the practice of shutting the damper in the pipe, as this will often drive the products of the combustion into the room; this might occur during the night, especially if the wind dies down, and the suffocating carbon dioxid and sulfur dioxid, as well as the more dangerous carbon monoxid, would be driven into the room. When sufficient air for complete combustion is not admitted below the fire, more carbon monoxid will result, and the full heating value of the fuel will not be obtained.—These conditions are represented by the equations—

$$C + O_2 = CO_2,$$

and in the upper part of the fire pot—

$$CO_2 + C = 2\,CO.$$

THE HOT-AIR FURNACE

Indirect radiation may be secured in the simplest way by the use of the ordinary **hot-air furnace.** Here air is brought from the outside and passes over the heated surface of the iron, and is then admitted to the room. If,

in addition to this, open grates or fireplaces are used, the heating is nearly uniform and the ventilation is satisfactory.

If a building is heated by a furnace, great care should be taken that the air that comes into the room is from out of doors and not from the cellar. The danger of ground air has been spoken of (p. 24), and this danger is still greater if it is contaminated with the gases that arise from decayed vegetables in the cellar. The amount of air coming into the furnace can be regulated if it is brought in from outside, and an excess, or more of the cold air than is thoroughly heated, can be avoided. If there is not enough air, the flues of the furnace are liable to become overheated, and the furnace will thus be damaged, and the air that does come in under these conditions will also be liable to contain carbon monoxid (see p. 15) and on this account be poisonous. The opening for the admission of fresh air should be so arranged that the winds will not seriously affect the amount of air admitted.

It is a common practice to take the air from the living rooms and the hall of the dwelling and return it over the furnace, thus using the same air over and over again. While this is no doubt economical, as far as expense of fuel is concerned, a part of the air at least should be taken from out of doors, and air should be reheated only in the coldest weather, and for warming the house in the morning.

There should always be some arrangement for adding moisture to air that is heated, as the capacity of heated air for taking up moisture is greatly increased (see p. 7); if moisture is not supplied, unpleasant sensations from the apparent dryness of the air are produced and there is greater liability to take cold. Pans of water are placed in the hot-air chamber of a furnace to allow the moisture

to evaporate and mix with the air which enters the room. An ordinary furnace will evaporate at least three gallons a day, in cold weather.

STEAM HEAT

In the use of **steam with indirect radiation**, it is convenient to have steam coils in the lower part of the building so situated that fresh air can pass over them, and then through suitable flues into the rooms above. Here again some provision can be made to keep the incoming air moist, by placing pans of water upon the steam coils.

Steam is generally used under a pressure below twenty pounds per square inch, so the temperature is not very much above 100° C. (212° F.), or " exhaust " steam from an engine may be used. In some systems high-pressure steam is employed, and in this case the temperature of the radiators is considerably above 100° C. If direct radiation is used, one disadvantage of this method of heating is that the air in the room is dry. In order to obtain heat from the steam, it must be condensed in the radiator, so there must be an opportunity for the water to run back freely to the boiler or to a steam trap.

HOT-WATER HEATERS

Water is used for heating on account of its great capacity for retaining heat. The hot water can be carried in pipes to some distance from the boiler, give up its heat, and then be returned by another series of pipes to the boiler. The water in the system may be under pressure, but it is usually carried in an open system, with a small tank at the top of the building, which is filled occasionally to supply the waste of evaporation or leakage; and vents must be

provided to allow the air that is dissolved in the water to escape. Under these conditions the hot water from the boiler in the cellar flows upward through the pipes and radiators and warms the building, and the heavier cold water runs back to the boiler and enters at the bottom through another set of pipes, and the heat keeps the water circulating. It should be noted that the difference in weight between the column of hot water and that of cold water is what keeps up the circulation in the system.

The **hot-water** system has this advantage over steam that as soon as the water is warm enough to circulate it begins to warm the room, and the heat is retained for a long time after the fire has been allowed to die down. In the case of steam there is no heat from the radiator till the water in the boiler is above the boiling point. With the use of hot water the temperature of the radiator is never above 100° C. and usually much below this, and with a suitable surface for evaporating water in the rooms the air will be agreeable. As the temperature of the radiating surface is lower than in the case of steam, the heating surface must be much larger, and so it is more expensive to install a hot-water system. This is no doubt the chief reason why it is not more generally used, and added to this is the greater liability to leaks, and the danger from freezing if not handled with care.

In the *direct-indirect* method of heating, air is brought from the outside behind or below a steam or hot-water radiator standing in the room, and is heated in its passage over the radiator. This is also theoretically very satisfactory, as good ventilation is secured, though it is not often attempted on a large scale.

ELECTRIC HEATING

At the present cost of electricity, it is not extensively used for heating, except in the case of street cars and small offices. With the increased use of water power to produce electricity, the use of this heating agent will no doubt soon be much more common. The use of electrical cooking devices is already quite large. They are especially adapted to small apartments, or rooms where there is extra danger from fire. One great advantage of the use of electricity over that of stoves is that the air of the room is not vitiated by electricity.

VENTILATION

But little attention is paid to ventilation by people in general, because they do not appreciate the injury to the body, as it is so gradual. The evil effect of bad air can be readily shown by the study of the health of those who are confined in close, badly ventilated barracks or tenements, or of workmen in crowded factories. Even domestic animals thrive much better in light, clean, well-ventilated stables. Consumption in some form is often the result of living in close, badly ventilated rooms. A practical demonstration of the fact that pure air is inimical to the growth of the bacilli that cause consumption is shown in the recent methods of treating this disease by requiring patients to live out of doors throughout the entire year, and in the establishment of sanatoria in elevated regions, where an abundance of fresh air is the most important part of the treatment.

Many public buildings have no provision for ventilation during that part of the year when they must be heated, and this is the case even with those buildings that are intended

to accommodate large audiences. There is a great want of appreciation of the necessity for ventilation, so that house renters never think of making any inquiry as to whether any facilities for ventilation exist or not. In many schools and assembly rooms there is no provision for ventilation except by opening windows and subjecting the audience to a dangerous draft. One reason for this, no doubt, is that we do not notice that air is impure until it is extremely impure. We suffer great discomfort, especially from high temperature, and then think that we need fresh air.

It is estimated that the daily **respiration** of each individual is 346 cu. ft.,[1] and the amount of carbon dioxid given off from the lungs in the same time is 16.25 cu. ft. It might seem that carbon dioxid that is produced by the combustion of oil and of gas and in the process of respiration, since it is heavier than the air, would sink to the bottom of the room, and remain there; but the fact is that an analysis of the air will show that on account of the diffusion of gases, the gas in question will be nearly uniformly distributed throughout the room. To such an extent is this the case that we expect to find greater discomfort in the gallery of a crowded hall than on the first floor, since the expired air being warmer tends to rise, notwithstanding its greater content of carbon dioxid gas.

The air of overcrowded, poorly ventilated rooms, as a result of life processes, is altered as follows: —

"There is a slight diminution in the amount of oxygen; there is an increase in the amount of carbon dioxid along with the organic pollution, resulting from the decomposition of perspiration and epithelium on the surface of the body, and from gastric and intestinal digestion and decomposition; and there is a slight elevation of tempera-

[1] J. S. Billings, "Ventilation and Heating," p. 88.

ture and addition of moisture. In the impure air there are more solid particles often organic upon which may be deposited either innocent or disease-producing bacteria, for the most part the former."

A prominent author,[1] in speaking of this "crowd poisoning," as it may be named, calls attention to the fact that it induces a general lowering of the vital processes, impairment of nutrition, and loss of muscular strength; the blood becomes laden with effete matters from diminished aëration; a craving for alcoholic stimulants follows on the nervous depression; and the subjects of this poisoning fall easy victims to disease. The prevalence of "consumption" among those workmen whose time is passed largely in badly ventilated and crowded shops, which was formerly charged to the use of "rebreathed" air, is now believed to be only remotely chargeable to these conditions; for the conditions produce lowered vitality and less resistance to infection by spores of disease, which may be inhaled with the dust, either in the workrooms or elsewhere.

After all that has been said, as noted in the previous paragraphs, about the history of our investigations on the cause of the disagreeable effects produced by breathing impure air, the consensus of opinion at the present time seems to be that "wherever in closed, crowded rooms certain impairment of health ensues, such as headache, dizziness, nausea, etc., these symptoms are to be attributed solely to heat retention." [2] Overheating seems to be the chief evil to be guarded against in the ventilation of the schoolroom or the home, and at the same time the air should be supplied with a sufficient quantity of

[1] Willoughby, "Hygiene for Students," p. 166.

[2] Baskerville, *Journal of Ind. and Eng. Chem.*, Vol. VI, p. 250.

moisture. Much of the inconvenience will be remedied if the air is not allowed to stagnate around the body. If in motion it will remove the excess of heat from the surface. No doubt one of the chief reasons why the sleeping porch has been found to be so advantageous is that these conditions do not allow a stagnation of air in the vicinity of the body.

Of the impurities mentioned, the carbon dioxid, which in moderate quantities is not poisonous, is the most readily determined as an index of the impurity of the air, so special attention is given to this substance (see p. 12).

Another **source of contamination** in a living room, which should not be neglected when the room is artificially lighted, is the products from the combustion of illuminating gas, oil, or candles. This not only decreases the per cent of oxygen and increases the per cent of carbon dioxid in the air, but it introduces other gases, such as sulfur dioxid and ammonium compounds. Ordinary burners use from 3 to 6 cu. ft. of gas per hour, and so in a large room there would be required from 1500 to 5000 cu. ft. of air per hour to properly dilute the products of combustion.

According to Parkes,[1] the amount of fresh air to be supplied in health during repose ought to be: —

For adult males,	3600 cu. ft. per hour for each person.
For adult females,	3000 cu. ft. per hour for each person.
For children,	2000 cu. ft. per hour for each person.

The following may be considered as a conservative estimate of the amount of air required in buildings of ordinary construction: [2] —

[1] "Text Book of Human Physiology."

[2] J. S. Billings, "Ventilation and Heating," p. 129.

	Cubic Feet of Air per Hour
Hospitals	3600 per bed.
Legislative assembly halls	3600 per seat.
Barracks, bedrooms, and workshops	3000 per person.
Schools and churches	2400 per person.
Theaters and audience halls	2000 per seat.
Office rooms	1800 per person.
Water closets and bath rooms	2400 each.
Dining rooms	1800 per person.

Those who are taking moderate exercise need one and one half times as much air, and during violent exercise three times as much air, as when at rest.

These amounts of air are much larger than those given by Morrin, the French writer, but in view of the contamination of indoor air from various sources, they do not seem to be too large. In the Boston Theater 50 cu. ft. per minute per capita is furnished. Pettenkofer says the amount of air should be from 23 to 28 cu. ft. per minute. Dr. Billings,[1] an authority on this subject, says that for audience halls 30 cu. ft. of air is necessary, and in legislative buildings the apparatus should be such that at least 45 cu. ft. of air per person per minute can be furnished, with a possibility of increasing to 60 cu. ft. At the Vienna Opera House, which is considered one of the best-ventilated buildings in the world, 15 cu. ft. of air per minute per capita is supplied.

In order to have good ventilation, the fresh air introduced into the room must be ample in volume; it must be free from contamination with dust and germs. It must be warmed in cold weather, and, if possible, cooled in warm weather, and it must be introduced so as not to cause a draft. There should be a sufficient quantity of air, so that the amount of carbon dioxid in the air at any

[1] *Loc. cit.*, p. 128.

time shall not be above six parts per ten thousand. Many buildings are now ventilated by drawing out the air, washing and purifying it and returning it to the rooms.

The ventilation may be **downward** or **upward**, and both of these methods have their advocates. The disadvantage of upward ventilation is that the heated air of the room is carried off very rapidly, thus increasing largely the cost of heating. Greater economy of heating is secured by drawing out the impure air from a point near the bottom of the room. If drawn off at the top, the heat does not diffuse throughout the room, and the floor is liable to be cold. The disadvantage of downward ventilation (that is, taking the impure air out at the bottom of the room) is that it is sometimes difficult to get the currents of air to move in this direction. The Chicago Auditorium, however, is ventilated in this way; 10,000,000 cu. ft. of air per hour is furnished, with a velocity of 1 ft. per second. The air is changed from $4\frac{1}{2}$ to 5 times per hour. This result is brought about by the use of four blowers to force air into the room, and three exhaust fans to take it out.

In general, it may be said that ventilation may be accomplished by **natural draft** or by a **forced draft.** The air may be forced into a room, and allowed to find its way out by flues, or it may be allowed to find its way into the room through the cracks, and be taken out by an exhaust fan. It is, however, greater economy of power to force air into a room than to draw it out by an exhaust fan. In some large chemical laboratories the tempered air is blown into the room by means of a fan, and then is carried out with a good draft by flues connected with hoods in the walls.[1]

As previously intimated, the most complete systems use both **pressure blowers** and **exhaust fans.** In some hospi-

[1] See also "A Text Book of Hygiene," Rohe and Robin, pp. 38–42.

tals (and in these buildings, if anywhere, pure air is necessary) the air is introduced through a perforated cornice at the top of the room, and is then drawn out a short distance above the floor through flues which are ventilated by exhaust fans.

Where there is no other way of securing a movement of a current of air, it is possible to cause the air to rise rapidly in flues at the side of the room, by having a gas jet or some source of heat in the flue. The best place for this is just above the openings, but these flues should be much larger than those usually provided. A system of down draft that works with more or less success, has been in use in school buildings for many years. In this case a fire is kept burning in the furnace, so as to assist in the removal of the foul air from the rooms and from the flues. Toilets are often ventilated through the furnace stack by this system.

When the **pressure blower** system is used, the air is drawn over the steam pipes in the winter (see p. 43), and it may be cooled by passing over refrigerating pipes, through which cold brine is circulated, in the summer. The air is sprayed before it enters the room to remove dust or smoke, or the dry air may be filtered through cotton or cheese cloth, in a long flue.

If large halls are lighted by gas, the burners should be placed outside the room, thus allowing the light to shine into the room through a glass dome. This avoids heating the room, and the products of combustion do not in this way contaminate the air. Much of the foul air of the room will escape also at the same time if openings are left in the ceiling near the place where the gas is burned.

Open grates may be used in connection with furnace or radiator heat to ventilate the ordinary dwelling. If stoves

are used in closed rooms, cold air from outside may be brought in below the stove, allowed to pass over it, and a flue may be provided near the floor for the escape of foul air, thus securing ventilation (see p. 41).

Various **other devices** have been suggested to ventilate an ordinary room. One of these is to bore gimlet holes in the walls; these are so small that the air cannot cause a draft, and yet they will admit a large amount of fresh air. An excellent plan, and one that can be easily adopted in any schoolroom, is to raise the lower sash and place a board about 5 in. wide below it, and then air will be admitted into the room between the two sashes and directed upward, so there will be no direct currents. A strip of plate glass is used in a similar way. This is so arranged that the air enters the room below the lower sash, as well as between the sashes. One disadvantage of opening the windows at the top is that the air may pass to the opposite side of the room, so those persons farthest away from the window will feel the draft, while those near by will not notice it.

The air in a well-ventilated room should be in motion, but this motion should not be over 3 or 4 ft. per second, for otherwise it becomes a "draft." The ordinary dwelling fortunately affords numerous openings where air from outside can enter, if the air within the room is removed by a chimney or a heated flue.

TESTING AIR

Experiment 19. Test for currents of air at the bottom and top of a room by the use of thistledown or a candle flame.

Experiment 20. Test the temperature at the top and bottom of a room, and in different localities.

Experiment 21. Test for the moisture in both a cold and a warm room by the use of the hygrometer.

Experiment 22. A "household test" for air, devised by Angus Smith,[1] is to place ½ oz. of clear limewater in a 10½ oz. bottle containing the air to be tested for carbon dioxid, cork it tightly, and if, on shaking, there is no precipitate, the air contains less than .06% of this gas, and is, therefore, fairly pure.

See Experiments 10 and 11 under Air.

[1] Kenwood, "Public Health Laboratory Work," p. 203.

CHAPTER IV

LIGHTING

We may properly consider that there are two kinds of light, natural and artificial. The most common methods of obtaining artificial light are by —

(1) Combustion.
(2) Chemical action.
(3) Phosphorescence.
(4) Electricity.

To obtain light, the body, if a solid, must be heated to incandescence, or if a gas it must be heated till it glows. A carbon filament, heated to incandescence in a vacuum, as in the incandescent electric light, is a familiar instance of this class of illumination. Again, by means of the oxyhydrogen blow-pipe, calcium oxid is heated to a white heat; and when magnesium is burned, the intense light is due to the incandescent particles of magnesium oxid. When charcoal is burned, the carbon is not hot enough to be a source of light, but only of heat. When wood is burned, although the wood itself does not volatilize, there are certain volatile hydrocarbons given off, and these have the property of becoming incandescent or the carbon in them does so, and thus light is obtained from the burning wood.

Ordinary **light-producing substances** may be divided

into solid, liquid, and gaseous. It is, however, the gaseous substance in either case that burns and gives the light. In the solid candle, for instance, the fat of the candle is melted by the heat radiated from the flame and becomes a liquid oil, and is then drawn up by capillarity into the wick, where a kind of distillation takes place and the oil is made into a gas which will burn. When any oil or liquid substance is burned in a lamp, it is already in a condition to be drawn up by capillarity, and is then volatilized as before. Illuminating gas is, however, delivered at the burner in a condition to be burned directly without any previous distillation, as that has already been done at the gas works.

The ordinary **candle flame** illustrates very well the theory of combustion. It is divided into three zones: an inner zone of unburned gas; a middle zone, where partial combustion takes place; and a third or outer zone of complete combustion, where there is very little light but much heat. It is in the second zone that the illumination takes place; here the carbon becomes incandescent or white-hot. The products of combustion are carbonic anhydrid and water, and as both these gases are transparent, they do not prevent the light from radiating outward. We are indebted to Michael Faraday for making a very thorough study of the nature of flame as long ago as 1835. In the candle flame the hottest point is at the end of the inner zone, and the interior of the flame is unburned gas.

Experiment 23. Press down into a candle flame, for an *instant* only, a sheet of white paper, and notice the ring of carbon deposited on it. In a similar way a ring of carbon may be deposited on a piece of glass, and the dark center of the candle can be seen on looking down inside the ring.

Experiment 24. Blow out the flame of a candle that is burning with a long wick, and after an instant relight the smoke at a little distance from the end of the wick. The distillation of gas proceeds for some time after the candle is extinguished.

COMBUSTION OF GAS

Ordinary **illuminating gas** may be burned in the bat-wing or fish-tail burner to produce light; or in the Bunsen burner, where there is enough air admitted into the bottom of the burner and mixed with the gas to give complete and rapid combustion, and consequently very little light.

EARLY ILLUMINATING DEVICES

The earliest **device for obtaining light** was perhaps the pine knot or the torch, and this was followed by the rush-light, and the link, which was a rope saturated with pitch. After this came a crude lamp made by allowing a wick to fall over the edge of a dish containing some liquid fat and then a lamp in which the wick came through the hole in the side of the vessel or in the lip. There are many very beautiful lamps of these types found in ancient ruins. It was also found possible to make a solid light-giving substance by drawing a piece of string through a lump of tallow, and later this was modified by casting a solid fat around a wick, and thus the candle came into use.

CANDLES

The making of **candles**, by surrounding thin wicks of pith or flax with tallow or wax, dates from a very early period. In 1313 they are mentioned among the expenditures of the Earl of Lancaster.[1] Molded candles were introduced into England in the fifteenth century.

[1] Groves and Thorp, "Chemical Technology," Vol. II, p. 69.

Candles are made from tallow, stearin, paraffin, wax, and spermaceti. Although tallow has been in use for a long time, there are serious objections to it because the fat melts at such a low temperature and drips. What was needed was a fat that had a higher melting point. This result was obtained by using a mixture of fatty acids produced from fats, instead of tallow.

Fats and oils are derived from both the vegetable and animal kingdoms. They are really compounds of organic acids with bodies belonging to the group called alcohols; that is, they are glyceryl salts of organic acids, mostly of the "fatty acid" group. The alcohol is usually glycerol or glycerin, $C_3H_5(OH)_3$, and the compounds are called glycerides. The acids most commonly found in these glycerides are stearic, palmitic, and oleic. Solid fats contain more of the glyceryl tri-stearate or "stearin" and the glyceryl tri-palmitate called "palmitin." The liquid fats consist largely of the glyceryl tri-oleate or "olein." (See Soap, p. 128.)

Tallow contains 75 % of stearin and olive oil only 25 %. One of the best products used in candle making is made by heating tallow until it melts, and then when it is partially cold putting it in bags in piles under a hydraulic press and squeezing out the liquid fat. This will be more fully discussed under Oleomargarine.

There are several methods for separating the fatty acid from glycerin. This may be done by the use of steam, with lime, and with sulfuric acid. The commonest method is to heat under pressure with water, and a small percentage of lime or zinc oxid, and afterward to distill with steam. This affords the two products, stearic acid, which earlier in the process is separated by gravitation, and glycerin, which is carried over with the steam; both of

these are marketable. The stearic acid thus produced is quite crystalline, and indeed too much so to use alone in the manufacture of candles, and in actual practice it is mixed with a little paraffin to prevent crumbling.

Two kinds of candles have been in use: dipped and molded. To make the former the wicks are dipped and allowed to cool and then repeatedly dipped again till the candle is large enough. A more modern method is to pour the melted fat into molds in which wicks have been previously suspended. Many attempts have been made to make a wick that will burn off at the end and not need snuffing. One of the best inventions in this line is the making of one thread of the twisted wick shorter than the rest so that the wick will be pulled over to one side and burned in the outer zone of the flame.

Paraffin is one of the last of the products obtained by the distillation of petroleum. (See p. 60.) Illuminating oils and lubricating oils distill over earlier in the process. Paraffin is in reality a mixture of hydrocarbons, having a high boiling point, and as it is a mixture it cannot be represented by a formula.

SPECIAL ILLUMINATING MATERIALS

There were some other interesting illuminating materials in use in the United States between the 40's and the 60's before kerosene was produced. One of these was **camphene**, which was simply refined turpentine. Another, which was intended to remedy some of the defects of camphene and prevent some of the smokiness of the flame, was called "**burning fluid**," and was a mixture of turpentine and alcohol. Various fixed oils, such as lard, whale, olive, colza, and poppy-seed, have been in use in lamps since the earliest times. Before the discovery

and utilization of Petroleum an oil, known as " coal oil," was obtained by the distillation of certain coals, and a " shale oil " was made by the destructive distillation of bituminous shales.

KEROSENE

Oil was first found in Pennsylvania in 1859 by Colonel Drake. **Kerosene** is one of the products that comes off in the distillation of petroleum or rock oil. This oil is obtained by boring to a depth of 600 to 1800 feet, and is frequently associated with natural gas. The product from a large number of wells is carrried by pipe lines hundreds of miles, even through a mountainous country, to a refinery. There are more than 3000 miles of these pipe lines from the oil regions of Pennsylvania and adjoining states to lake or sea ports. In these pipes a barrel of oil moves forward every seven seconds, or at each stroke of the pump which keeps the oil moving. In the process of refining, the oil is heated in immense retorts, and the more volatile products are distilled and condensed by passing through pipes surrounded by water. At a little higher temperature another product is given off, and another at a still higher, till at last a residue of paraffin remains, and this may be distilled off, leaving only a small amount of coke in the retort. Often the distillation is carried on in two stages, the " light oils " being first distilled, and then in another still the " heavy oils."

DISTILLATES FROM PENNSYLVANIA PETROLEUM

The commercial products obtained by the distillation of crude petroleum have various trade names, but the generally accepted classes of products are the following, beginning with the lightest : [1] —

[1] Sadtler, " Industrial Organic Chemistry," 4th ed., p. 29.

1. Cymogene, which is gaseous at ordinary temperatures. It may be used in the manufacture of artificial ice.

2. Rhigolene, which may be condensed to a liquid by the use of ice and salt. It is used as an anæsthetic.

3. Petroleum ether, which boils from 40° to 70° C. It is used as a solvent for caoutchouc.

4. Gasolene, which boils from 70° to 90° C. It is used as fuel and in gasolene engines, forming an explosive mixture with air. (It consists mostly of hexane (C_6H_{14}).)

5. Naphtha, which boils at 80° to 110° C. It is used in vapor lamps, and as a solvent for resins.

6. Ligroine, which boils at from 80° to 120° C. It is used as a solvent.

7. Benzine,[1] which boils at 120° to 150° C. It is used as a substitute for turpentine, and as a solvent.

8. Kerosene or Burning Oil, which is graded by its color and "fire test." It has a flash test of 110° to 150° F.

9. Lubricating oils, which have a gravity of from 32° to 38° Beaumé.

10. Paraffin, which is of different degrees of hardness, and like all the other products of variable composition. It is a solid, melting at from 51.°6 to 57.°3 C., and is used in candle making, in making water-proof papers, chewing gums, etc. Vaseline and petrolatum may be obtained from a mixture of some of the distillates. All these products are *mixtures* of hydrocarbons of the methane series.

The crude kerosene is purified by treatment with sulfuric acid and alkali, and subsequently by bleaching in tanks with glass roofs. There is often a temptation to mix the lighter oils with the heavier, especially when the

[1] This is an entirely different product from the "benzene" (C_6H_6) which is a coal tar distillate.

former are cheaper and there is not so much use for them. These light oils, however, increase the danger of explosions when the oil is burned in a lamp. If a vapor is given off at the ordinary room temperature in the summer, or the lamp is heated so that a vapor may be given off from the oil, it may be mixed with air in such proportions that an explosion will result. The following grades of burning oil are on the market: —

110° Fire test (Standard white).
120° " " (Prime white).
150° " " (Water white).

In many states and countries laws have been passed fixing the " **flash point**," or the " **fire test**," of the oil, as it is called. By the " flash point " is understood the temperature at which a volatile vapor is given off that will produce an explosion. The " fire test " is the temperature at which the oil will take fire and continue to burn. The laws of Ohio require a flash point not below 110° F. Those of New York require a higher point. In Kansas the requirement is the same as in Ohio, and the Foster cup is designated as the official tester.

A simple *flash-point apparatus* may be made by the use of a small beaker filled about half full of kerosene, supported in a larger beaker or vessel containing water. The oil may be heated at a rate not faster than two degrees in a minute. Over the beaker containing the kerosene is placed a metallic cover with a large opening. In this opening is placed a thermometer, with the bulb in the kerosene. A very small flame is applied at the opening above the kerosene from time to time, and a record is made of the temperature at which the slight explosion of the gas extinguishes the flame. This is the flash point.

Experiment 25. Pour a small quantity of kerosene into a saucer, and touch it with a lighted match. The oil should not be ignited.

Experiment 26. Pour about 2 cc. of gasoline into a saucer, and notice how readily it takes fire, and the smoky character of the flame.

Experiment 27. Use a "Foster cup," or the flash-point apparatus described above, for testing the flash point of several samples of kerosene.[1]

ILLUMINATING GAS

Aside from natural gas, which has already been discussed under fuels, the gas used for lighting is either coal gas, water gas, air gas, Pintsch gas, Blau gas, or acetylene gas.

Illuminating gas, known as coal gas, was discovered by Clayton in 1664, and used for lighting a dwelling in London, by William Murdock, in 1792. It did not come into general use, however, for many years, for London was not lighted by gas till 1812, and Paris in 1815.

Gas is made by the distillation of soft coal in fire-clay retorts, heated to a cherry red by a fire of coke, which is maintained beneath them. In addition to the gas, there are several by-products made, including gas carbon, which is found attached to the inside of the retorts, coke, ammoniacal water, and coal tar. The injurious gaseous constituents, including the sulfur compounds, are removed from the gas by cooling, washing, and passing it through lime purifiers, and then the gas is stored in large gas holders, for distribution through the city mains. A ton of coal will yield from 8000 to 14,000 cu. ft. of gas.

The gas carbon mentioned above is used in making electric-light pencils and in batteries. The ammoniacal liquor is used for the manufacture of all the ammonia compounds of commerce. The coke is partly burned

[1] B. Redwood, "Petroleum and its Products," Vol. II.

under the retorts, and the rest is sold as fuel, and finally the coal tar is distilled to make a variety of valuable organic substances, including many photographic developers, the aniline dyes, carbolic acid, oil of wintergreen, oil of " mirbane," salicylic acid, etc.

WATER GAS

Water gas is made by passing steam over incandescent coke or anthracite coal. This gives a mixture of the two gases, hydrogen and carbon monoxid, thus : —

$$C + 2\ H_2O = CO_2 + 2\ H_2.$$
$$C + CO_2 = 2\ CO.$$

These gases, however, give no light, and so the gas is enriched by injecting into the generator, by means of a jet of steam, some crude petroleum, which at the high temperature breaks up into volatile hydrocarbons, which furnish light when burned. On account of economy in manufacture, this gas is used instead of coal gas in many American cities. It is, however, much more poisonous, if breathed, than coal gas.

AIR GAS

Air gas was much used for lighting detached buildings before electric-lighting plants could be so cheaply installed. In this process air is forced through vessels containing gasoline, and some of the vapor is thus carried with the air into the pipes. What is burned then is really gasoline vapor. In order to avoid danger from fire, the liquid gasoline is stored underground outside the building.

PINTSCH GAS

The method of making Pintsch gas, or oil gas, was invented in 1873, and it has found great favor as a com-

pressed gas to use for lighting cars, steamboats, lighthouses, and isolated buildings. It is made from crude oil, by vaporizing it in cast-iron retorts. The oil is "cracked" in the upper chamber of the apparatus, and the vapor is passed into the lower chamber, which is heated nearly to 1000° C. to "fix" the vapors and form permanent gases.

BLAUGAS

A process for making what is known as "Blaugas" was perfected by Herman Blau in 1901. One of the products produced by the fractional distillation of petroleum is known as "gas oil." When this is heated to a high temperature in an apparatus free from air, it is decomposed, and oil gas is one of the products of the decomposition. This gas is liquefied at ordinary temperatures under a pressure of 20 atmospheres and the liquid is stored in strong steel bottles. These may be readily transported, and when the pressure is released the liquid again becomes a gas and can be stored in an expansion tank, from which it can be burned in the ordinary burners. It burns with a bright light, and a flame having a high temperature.

ACETYLENE GAS

Acetylene gas has come into use recently, since calcium carbid (CaC_2) has been cheaply made in the electric furnace by the use of powdered coke and lime. When calcium carbid is treated with water, acetylene gas is produced thus: —

$$CaC_2 + 2\ H_2O = Ca(OH)_2 + C_2H_2.$$

This gas produces a very brilliant light, as there is much incandescent carbon in the flame. A burner which con-

sumes only half a foot of gas per hour is usually the most efficient, especially when the gas is burned under considerable pressure. It is not safe to compress the gas to more than two atmospheres, as an explosion is liable to occur. The gas finds considerable use in country houses, on yachts, automobiles, and bicycles. A ton of calcium carbid of 80% purity will produce 10,000 cu. ft. of acetylene gas.[1] Acetylene is freely soluble in acetone $(CH_3)_2CO$. A solution of the gas in acetone under pressure is furnished for lighting automobiles. The gas is absorbed by asbestos contained in the steel cylinder.

COMPOSITION OF ILLUMINATING GASES

Illuminating gas gives the best results when burned at a water pressure of not over 1½ in. If the pressure is too great, the gas "blows" and the light is decreased. The amount of gas burned in an ordinary burner is from 2 to 8 cu. ft. per hour, dependent on the rating or size of the burner and the pressure of the gas. A comparison of the coal, water, oil, and natural gas may be made by inspection of the following analyses: —

	Coal	Water[2] (Carbureted)	Pintsch or Oil[2]	Natural Gas[3]
Carbon dioxid .	1.22	3.00	—	.25
Olefiant gas, etc.	5.30	16.60	45.00	.35
Carbon monoxid	7.50	26.10	—	.41
Marsh gas . . .	38.11	19.80	38.80	93.35
Nitrogen . . .	—	2.40	1.10	3.41
Oxygen . . .	.22	—	—	.39
Hydrogen . . .	47.65	32.10	—	1.64
Ethane	—	—	14.60	—
Hydrogen sulfid .	—	—	—	.20

[1] Thorp, "Outlines of Industrial Chemistry," p. 293. [2] *Ibid.*, p. 294.
[3] Min. Res. of U. S., 1893. Dept. Interior. Anal. Edw. Orton.

From these analyses it is evident that water gas, if breathed, would be the most liable to produce death, since it contains the most carbon monoxid. Natural gas contains less carbon monoxid than coal gas.

Experiment 28. Test coal gas or any combustible gas for carbon dioxid, by passing it through limewater contained in a Woulfe bottle. For this purpose, put through a hole in one cork a tube bent at a right angle, with one limb extending to the bottom of the bottle, and through a hole in the other cork a tube of the same size, bent at a right angle, and passing just through the cork. Fill the bottle half full of limewater, allow the gas to bubble slowly through this, and light the gas that escapes. After a time, dependent on the amount of carbon dioxid in the gas, there will be a deposit of calcium carbonate in the bottle.

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

Experiment 29. To test the gas for hydrogen sulfid, allow a slow stream to pass through the empty Woulfe bottle arranged as above, in which is suspended a piece of filter paper which has been dipped in a solution of lead acetate. The paper will turn brown or black after a time on account of the formation of lead sulfid on the paper.

Experiment 30. To test the pressure of the coal gas used, the apparatus mentioned in Experiment 28 may be used. If the bottle is small, a straight tube about eight inches (20 cm.) long may be put in to take the place of the longer bent tube. Fill the bottle about one third full of water. Connect the gas cock by means of a rubber tube to the shorter tube, and measure the height of the column of water raised by the pressure of the gas.

Experiment 31. Learn to read a gas or water meter. The figures on the dial having the highest number are read first, and in case a pointer is very nearly upon any figure, notice by reference to the next lower dial whether it is above or below that figure, and read accordingly.

Experiment 32. To make acetylene gas, put a small quantity of calcium carbid in a test tube. Place this in a rack or a test-tube holder, and carefully bring into the tube a few drops of water. The gas will be immediately given off and may be lighted.

Experiment 33. To make an acetylene lamp use a heavy 16 oz. flask or bottle provided with a cork having two holes. In one of these holes put a dropping funnel, with the tube extending nearly to the bottom of the flask, in the other hole a tube bent at a right angle. Place about an ounce of calcium carbid in the flask, and allow water to drop on it, a very small quantity at a time, by the use of the dropping funnel. Pass the gas evolved through another flask or Woulfe bottle containing some lumps of calcium carbid; this will dry the evolved gas. In one tubulature of the drying bottle put a straight tube, to the top of which is fitted, by a short rubber tube, a special lava tip designed for burning acetylene gas which uses one half a foot of gas per hour. A brilliant light will be obtained.

Experiment 34. In the incomplete combustion of illuminating gas small quantities of acetylene are formed. Study the phenomenon which takes place when a Bunsen burner "strikes back" and burns at the base. Notice especially the odor.

LAMPS AND BURNERS

A great variety of devices have been used to utilize oils and gas and get the greatest possible illuminating value from them. With a lamp, where kerosene or some oil is used as the combustible, the glass chimney came into use to increase the draft, and prevent smoking. If the substance burned is rich in carbon, as is the case with kerosene, this is particularly necessary. Another device to attain the same end that has been used in lighthouses is the use of a pump, run by clockwork, to keep the wick, especially of a large lamp, saturated with oil. A

blower, concealed in the base of the lamp, has also been introduced, to avoid the use of a chimney.

The invention of the Argand lamp in 1786, which was applied both to oil and gas, and in which the air enters the inside of the circular flame, was a distinct advance in illumination. The student lamp is of this type. The flat flame of the gas burner is obtained either in the "bat-wing" tip or the "fish-tail" burner. In the former, the gas comes out through a lava tip, which has a narrow slit in the top; in the latter, the gas comes out through two opposite openings, usually in a metallic tip, and the resultant of these two currents of gas is a flat flame, at a right angle to the currents of gas.

INCANDESCENT GAS LIGHTS

On account of the fact that much of the gas in common use is of low candle power, and yet has great "fuel value," numerous attempts have been made to utilize this heat to produce light. Passing over many of the systems in use, the most practical at the present time is the Welsbach system. This was invented by C. Auer von Welsbach in 1885–1887. This lamp consists of a Bunsen burner over which is suspended a "mantle" of the oxids of such rare earths as cerium, thorium, yttrium, or zirconium. These oxids are obtained from the mineral monazite, which is mined extensively in North Carolina and Brazil. The best results are obtained by using a mixture of 99% of thoria and 1% of ceria. A cylinder of cotton is soaked in the nitrates of these metals, and one end is gathered into a ring by a thread of asbestos. After it has been dried, the cotton is burned off, and the oxids are worked into shape upon a form. Then, in

order to preserve this fragile material, it is plunged into a bath of collodion, paraffin, or some similar substance which stiffens it. This latter material is burned off when the mantle is put in place over the Bunsen burner. The "life" of these mantles is from 500 to 1000 hr., and even if they have not become ruptured, after a time their candle power is very much lowered. In one experiment when burning 2.5 cu. ft. of gas per hour, at one inch pressure, at first 25.6 candle power was obtained, after 500 hr. only 18 candle power, and at the end of 1000 hr. 13.7 candle power.

This kind of burner, which is designed to utilize the heat of the gas, produces a high candle-power light, uses a minimum of gas, and is satisfactory with natural gas, water gas that has not been carbureted, or any gas that is a poor light producer.

Experiment 35. To show the principle of light due to an incandescent solid, burn a piece of magnesium ribbon, or better still, heat a piece of calcium oxid in the flame of the oxyhydrogen burner.

ELECTRIC LIGHTS

In the modern method of lighting by electricity the common systems are the use of the arc light, in which pencils of gas carbon are heated by the electric current; the incandescent, in which a filament of carbon contained in a bulb from which the air has been fully exhausted is heated by the passage of the current; the tantalum lamp, in which the metal tantalum is used as the incandescent material; the tungsten light; the inclosed arc; the mercury vapor lamp; and the Nernst lamp. In these cases some highly heated solid gives out the light.

LIGHTING SYSTEMS

Most of the lights that have been mentioned are, at the best, wasteful, because we get heat and comparatively little light, when light and not heat is desired. Experiments have been made on the phenomenon of phosphorescence, and on the light of the firefly, that show how much superior this is to any light devised by man. There seems to be no reason why man cannot hope to perfect some system of lighting that shall be as economical, and this is no doubt the light of the future.

A recent author[1] quotes a table of **light efficiencies** which shows the relative amount of energy actually utilized from various sources as light:—

Fireflies	about 100 per cent
Acetylene flame	4 to 5 per cent
Welsbach burner	4 to 5 per cent
Carbon filament, electric (4 watts per candle)	2 to 3 per cent
Tungsten filaments, electric (1.25 watts per candle)	8 to 10 per cent
Electric arcs	8 to 17 per cent
Mercury vapor electric lamps (glass)	5 to 6 per cent
Nernst glower	5 per cent

[1] "Chemistry of Familiar Things," Sadtler, p. 38.

CHAPTER V

WATER

As water is so essential to human life, it is evident that a study of its occurrence and liability to contamination may be undertaken with great profit. It is composed of two simple elements, hydrogen and oxygen, both invisible gases, and the purest water is, of course, that which is formed by the union of these gases.

Water, when it is condensed in the clouds, is comparatively pure, and as it falls through the atmosphere it dissolves certain gases that are present in the air, and at the same time washes the air free from suspended organic and inorganic dust and bacteria. We are familiar with practically pure water in the form of distilled water, which is odorless and tasteless but to many is not agreeable as drinking water, because it does not contain the dissolved gases of the atmosphere nor the mineral salts to which they are accustomed. If it is aërated by shaking with air, and a very small quantity of salt is added, it becomes much more agreeable as a beverage.

Natural waters may be divided into: rain water, which we collect in cisterns, spring water, brook, river, lake, well (both shallow and artesian), and, finally, sea water. There is another class of waters which are especially interesting from a medicinal standpoint, viz. mineral waters.

Cistern water may be collected practically pure, if it falls on a metallic or slate roof, and the first water of a rain is used to thoroughly wash the roof. A well-painted shingle roof may also be used for collecting the water, if sufficient care is exercised in washing the roof. The water of a cistern should be aërated by the use of some kind of a chain or bucket pump that will carry air into the water. This may be used as an auxiliary means of obtaining water from the cistern, even if an ordinary suction pump is used for domestic supply.

Spring water, when it has flowed through sandstone or granite in an unpopulated region, is usually pure and free from mineral matter. In limestone countries, however, spring water is liable to become loaded with the mineral substances of the rocks and soil through which it percolates; and on some of the alkali plains it becomes very strongly impregnated with mineral matter. There is a constant tendency for the mineral matter to concentrate in river water, and these waters, which contain the soluble materials of the soil, finally accumulate in the ocean. Dilution with nearly pure surface waters often prevents river water from increasing in mineral salts. The gases of the atmosphere, especially the carbon dioxid, assist very materially in the solution of some of the rocks. Spring water may also contain organic matter from peat swamps as well as dead algæ and leaves which usually give it a brownish color.

River water partakes of the character of the springs and brooks which feed it, and it is also liable to become contaminated from refuse and sewage which is poured into it from inhabited regions. As a large stream is so often used to carry off the " waste of civilization," in the form of sewage, it is seldom, in a well-populated district,

that river water can be used with safety as a source of supply without some preliminary treatment by filtration.

The water of the Great Lakes would be of the very best quality were it not for the fact that it is difficult to dispose of the sewage of the cities on the banks without contaminating the water supply. This difficulty has been partially overcome, in many instances, by tunneling out several miles under the lake to an " intake " to get better water and by purifying the sewage. In the case of Chicago, by pumping the water containing the sewage through a drainage canal away from the lake into the Illinois River, the water supply is, to some extent, protected.

The water of wells will be pure or impure as the soil around them is pure or contaminated. Generally speaking, the water of bored and cased wells is purer than that of ordinary, shallow, dug wells, and the water of artesian wells, especially those which penetrate the earth to the depth of from 300 to 1000 ft., is usually better than that from shallow wells. As an ordinary well is but a hole in the ground, it naturally collects the surface impurities in the vicinity, and in cities and large towns this water is liable to be very impure. It may contain mineral salts, but the most dangerous impurities are of an organic nature. The character of these organic impurities is significant, as it is a key to the past history of the water and often reveals the fact that it has percolated through soil contaminated with sewage or the waste material from cesspools. As a district becomes more thickly populated, there may come a time when the soil is saturated with filth, and then every rain will cause some of this to flow into the well.

Although the water of wells is liable to be impure from cracks in the soil through which the foul water of drains or cesspools has entered, yet a commonly neglected source of infection is the surface drainage that may find its way into the well, because it is not carefully covered. When the water is pumped out and allowed to fall on dirty planks, where chickens and other animals resort, there is every opportunity for contamination. The same remark applies to cisterns, which sometimes receive not only the drainage of the soil, but of the dooryard where all the slops from the house are thrown.

Artesian well water is usually free from dangerous organic matter. The term "artesian," a name derived from the province of Artois in France, where these wells were first used, applies, strictly speaking, to deep, flowing wells. In the United States there is a large area in northern Florida, and one in the vicinity of Charleston, South Carolina, also in Texas, in Kansas, and in California, where an abundance of water is supplied by artesian wells. In the city of Memphis, Tennessee, where some years ago there was an epidemic of yellow fever, great pains has been taken to obtain pure artesian water from deep wells. The analysis of this water, which was made some years ago by the author, showed it to be exceptionally pure, and the health of the city has been very much improved since its introduction. Some artesian wells have penetrated to such a depth or through such strata, that the water becomes impregnated with too much mineral matter, so that it cannot be used for domestic purposes. This is the case, for instance, with a well bored at St. Louis to the depth of over 2000 ft. for supplying a brewery. The water contained so much salt that it could not be used.

MINERAL WATERS

Mineral waters are those which contain an excess of some ordinary ingredients, or small quantities of some rare ingredients, and which on this account are used as remedial agents. There are besides these certain waters on the market, known as "table waters," which are simply very pure, and are recommended by physicians because they may be taken in large quantities and will produce good results on account of the quantity used.

I. MINERAL SUBSTANCES IN WATER

Some of the mineral substances found in natural waters and in mineral waters are the following: sodium, calcium, magnesium, iron, aluminum, lithium, and potassium, combined as silicates, sulfates, chlorids, carbonates, bicarbonates, and sometimes as borates and arsenates. Common mineral substances in waters may be tested for as follows: In making the tests for mineral substance in water, it is advisable to first test the water supply of the laboratory, and if it does not contain the substance tested for, then use a strong mineral water of known composition, like Apollinaris, Hunyadi-Janos, Manitou or Congress water.

Experiment 36. Test for calcium in water that does not contain much iron by adding to it some ammonium chlorid, ammonium hydroxid, and ammonium oxalate. The formation of a white precipitate of calcium oxalate, especially after boiling, indicates the presence of calcium.

Experiment 37. Test for magnesium by first filtering off the calcium oxalate, if any is precipitated in the previous experiment, and adding to the filtrate, which should contain some ammonium chlorid and ammonium hydroxid, hydrogen sodium

phosphate. The formation of a white crystalline precipitate of ammonium magnesium phosphate, especially upon shaking, indicates the presence of magnesium.

Experiment 38. Test for iron as a ferric compound by adding a few drops of hydrochloric acid and some potassium ferrocyanid. The formation of a dark blue precipitate (Prussian blue) shows the presence of ferric salts. To test for ferrous salts, add to some of the water a few drops of hydrochloric acid and potassium ferricyanid. The formation of a blue precipitate indicates the presence of ferrous compounds.

Experiment 39. Another excellent test for ferric compounds is to add to a slightly acidified sample of the water a few drops of potassium sulfocyanate. The production of a red color indicates iron.

Experiment 40. Test for aluminum by adding to the water a few drops of ammonium chlorid and ammonium hydroxid in excess. The formation of a white flocculent precipitate, especially upon warming and allowing the solution to stand, indicates aluminum. In the presence of a considerable quantity of a ferric compound, the iron will be thrown down as a reddish precipitate, thus obscuring the aluminum hydroxid precipitate.

Experiment 41. To test for lead, add to a sample of water, acidified with hydrochloric acid, a little hydrogen sulfid water. The formation of a black or brownish coloration will indicate lead.

Experiment 42. In order to show how readily water, especially when pure, attacks lead, scrape a piece of sheet lead till it is bright and clean. Place it in a beaker of distilled water, and allow to stand for an hour or more. Remove the lead from the water and test the water for lead in solution by the use of hydrogen sulfid water.

Experiment 43. Test for sulfates by acidifying a sample of the water with hydrochloric acid, and adding a few drops

of barium chlorid. The formation of a dense white precipitate of barium sulfate, especially after boiling, indicates the presence of sulfates.

Experiment 44. To test for chlorids, add a few drops of nitric acid to the sample, and then silver nitrate. The formation of a white precipitate of silver chlorid indicates chlorids.

Experiment 45. To test for the total amount of mineral matter in the water, evaporate from 100 cc. to 200 cc. in a small weighed porcelain or platinum dish on a water bath. Dry the residue at 120° C., and weigh. Calculate the weight in terms of grams per liter. (The dish can be weighed on the ordinary horn-pan balance.)

Experiment 46. To test for carbonates, add a few drops of hydrochloric acid to the residue obtained in the previous experiment. If carbonates are present, there will be an effervescence on account of the escape of carbon dioxid gas. This solution may then be tested for potassium and sodium by dipping into it a platinum wire, which is heated in the Bunsen burner, and the flame can be examined with the spectroscope.

Experiment 47. To test for sulfur or hydrogen sulfid in a water like that from sulfur springs, plunge a silver coin into the water, and in the presence of soluble sulfids it will be quickly blackened on account of the formation of silver sulfid, Ag_2S.

HARD WATERS

Some waters contain large quantities of calcium, magnesium, iron, and aluminum. Those which contain these metals associated with the carbonate radical making calcium acid carbonate, magnesium acid carbonate, etc., are called *temporarily hard* waters, and those which contain calcium, magnesium, iron, or aluminum sulfates or chlorids, are called *permanently hard* waters. This distinction is made because the carbonate waters can be

readily softened by adding to them limewater in sufficient quantity, while it is much more difficult to soften the permanently hard waters. Another reason for this distinction is that a considerable quantity of the mineral matter is precipitated by boiling, in accordance with the equation: —

$$CaH_2(CO_3)_2 + \text{heat} = \underline{CaCO_3} + CO_2 + H_2O.$$

The difference between the hard and soft water may be readily shown by the action of a soap solution upon the two varieties.

Hard waters produce serious inconvenience when used in steam boilers, depositing a scale of greater or less thickness, which causes great loss of fuel by interfering with the transmission of heat to the water, and is liable, if it becomes thick enough, to allow the iron to become overheated, and greatly increase the tendency to explosion. The same kind of a scale is often found in a teakettle when hard water is used. There is an immense advantage in substituting soft water for hard when the item of soap is considered. It is estimated that in Glasgow, where the soft water of Loch Katrine was substituted for hard water, there was a saving in soap to the inhabitants of the city of nearly $200,000 annually.

For a long time it was believed that the disease " goiter " was due to the use of certain kinds of hard water, and the prevalence of this disease in some parts of Switzerland, France, Austria, India, and Derbyshire, England, was cited as proof that this was the case. In some cases, as in the city of Vienna,[1] there does seem to be a relation between the water used and the prevalence of the disease. Some have thought that a microörganism in the water

[1] " Preventive Medicine and Hygiene," Rosenau, p. 807.

caused the disease, but this theory also remains to be proved. Lobenhoffer believes that the cause of goiter is a purely chemical substratum substance, which enters the water as a toxin but is surely destroyed at 70° C.

Experiment 48. Prepare a sample of very hard water by adding some calcium chlorid to a sample of ordinary water, and pour this into a tall cylinder. Add to this some soap solution,[1] shake thoroughly, and notice how many cubic centimeters of the soap solution must be used before a permanent lather is produced in the water. Compare this with a similar experiment made with soft or distilled water. Notice also the abundant precipitate of " lime soap " in the hard water.

II. ORGANIC MATTER IN WATER

The mineral constituents of water: those which give character to the so-called mineral waters, which make water hard, which give saltness to brine, and the peculiar characteristics to the " alkali " waters of the plains, have been previously discussed. There are, however, other substances in waters which it may not be possible to detect there either by the sense of taste, smell, or sight, and yet these substances, which constitute the " organic matter," are from a sanitary standpoint of the greatest importance.

As has been stated, the mineral matter comes from the decomposition of the rocks and of the soil through which the water percolates. In a similar way, the organic material comes from the soil through which the water passes, or over which it runs. It is difficult to tell the source of the organic matter from a simple analysis of

[1] To make a soap solution Mason ("Water Supply," p. 360) recommends to use 10 g. of Castile soap, scraped into fine shavings, and dissolved in a liter of alcohol diluted with one third water. Filter, if not clear, and keep in a tightly stoppered bottle.

the water. It may come from peat swamps in which decomposing vegetable matter has remained for a long time in contact with the water; it may come from the decayed leaves or wood; or, what is much worse, it may be from decomposed animal matter, which finds its way into a stream or well from some cesspool or barnyard or foul kitchen drain.

The chemist in making a *sanitary analysis* of a water determines its color, odor, and turbidity, as well as the residue left on evaporation, loss on ignition of this residue, free ammonia, albuminoid ammonia, nitrogen present in nitrites, nitrogen present in nitrates, chlorin, oxygen consuming power, and hardness. He also studies the number and character of the bacteria which are present. From a consideration of *all this data;* from a knowledge of the locality from which the water comes; from comparisons with other waters from the same locality, all taken together he is able to form an opinion as to whether the water is safe for domestic use.

The ammonia is not in itself injurious, but is an index of nitrogenous matter, which is liable to be dangerous. Whenever there is matter of this kind, numerous bacteria find the conditions suited to their growth.

Free ammonia is usually considered to be indicative of recent contamination, especially of animal origin, while albuminoid ammonia indicates more especially nitrogenous matter that has not undergone sufficient decomposition for the formation of ammonia compounds. If the water changes in its ammonia content from day to day, this also shows that it is in a dangerous condition. As to the amount of these substances which may be allowed in a good water, it is practically impossible to set a standard, as local conditions are so variable. What would be a

fair standard for water from one locality, would not apply at all to water from a different locality. Professor Mason reports an excellent mountain stream containing .055 part of free ammonia and .230 of albuminoid ammonia per million. Professor Mallet reports the average of a number of city supplies considered good as containing .152 part of albuminoid ammonia, and Professor Leeds would limit the amount to free ammonia .01 to .12 per million and albuminoid ammonia .10 to .28 per million. It is interesting to note that iron waters always contain much free ammonia.

Free ammonia is determined in a water by distilling a half liter and testing the several portions of 50 cc. of the distillate with Nessler solution. The brown color produced is compared with that obtained in solutions of ammonia of known composition. When the free ammonia has been distilled off, some alkaline permanganate solution is added, and the ammonia thus set free on distillation is determined as before. This is the albuminoid ammonia.

The nitrites in water are indicative of a changing condition of oxidation, which is completed when the nitrogenous bodies are changed to nitrates by bacterial action or by oxidation of nitrites. The determination of nitrates is considered of value in supplying some data as to the previous history of water. If the nitrates are abundant, this indicates that at some earlier stage in the history of the water it may have been contaminated with sewage, and although there may be no free ammonia present, we have no proof that the pathogenic germs, that once existed in the water, are destroyed by the oxidation which the ammonia has undergone.

In regard to the nitrates, it is evident that there must

be some of these in natural waters, for both nitrites and nitrates are washed out of the air and carried into the soil, and we depend upon the nitrates as well as other nitrogenous compounds in the soil to assist in the growth of plants. The determination of nitrates is regarded by Mallet as of great importance, and he places the figures for the amount as averaging 0.42, the extreme limit being 1.04 parts per million. He notices that waters known to be polluted contain sometimes from 7.239 to 28.403 parts of nitrogen as nitrates per million. The average for American rivers is given as from 1.11 to 3.89 parts per million, and the author has found in city wells from 14.5 to 150 parts per million of nitrogen as nitrates.

The Rivers Pollution Commission (Eng.) gives the following averages from 589 unpolluted waters for nitrogen as nitrites and nitrates.

	Parts per Million
Rain water	.03
Upland surface	.09
Deep well	4.95
Spring	3.83

In some localities the determination of chlorin may be of value, especially where the normal chlorin content of the ground water is known. The soil of several of the New England states has been thoroughly studied, the normal amount of chlorin for each locality has been pretty accurately determined, and a map has been prepared showing where equal amounts of chlorin are found. An increase in chlorin would show probable pollution with sewage. In many places, however, there is so much salt in the soil that the determination of chlorin is of no value.

Experiment 49. To make Nessler's solution, dissolve 8 g. of mercuric chlorid, $HgCl_2$, in a quarter of a liter of pure water. Dissolve 17 g. of potassium iodid, KI, in 100 cc. of pure water. Pour the first solution into the second until a slight permanent precipitate, which does not disappear on shaking, is produced. Add 80 g. of solid potassium hydroxid, KOH, dilute to one half a liter, cool, and add drop by drop some of the mercuric chlorid solution till there is a slight permanent precipitate. Allow to settle for some time, and pour off the clear yellowish solution for use. Old "Nessler Solution" is better than one which is recently made.

Experiment 50. Test a sample of the distilled water used in the laboratory for ammonia by placing some of it in a long test tube, or a so-called Nessler tube, standing on a piece of white paper, and adding to it 2 cc. of Nessler solution. Notice the brown tint of the solution.

Experiment 51. Distill about 500 cc. of well or river water slowly from a liter retort, condense the steam by a Liebig's condenser or in a flask floating in a pan of water, and test about 50 cc. in a long tube by adding 2 cc. of Nessler solution, and allowing the mixture to stand a few minutes. Unless the water is very pure, there will be a distinct brown coloration.

Experiment 52. To test for nitrates in water, add to about 10 cc. in a test tube an equal quantity of concentrated sulfuric acid and cool the solution. Then add to this cautiously, without mixing, a strong solution of ferrous sulfate. The formation of a brown ring where the two liquids come together indicates the presence of nitrates. This test is delicate only to about ten parts of nitric acid in a million parts of water. A very small crystal of saltpeter, potassium nitrate, may be used in the water to show the test.

Experiment 53. To test for organic matter when present in *large quantity*, as in a foul cistern water, add to a sample of water, contained in a tall stoppered cylinder, a little dilute sulfuric acid and a few cubic centimeters of a 1% solution of potassium permanganate. The purple color of this solution is "discharged"

by shaking with water containing organic matter, so the amount of organic matter may be estimated relatively by noticing how much permanganate must be used to produce a permanent purple color in the water. (This same reagent may be used practically on a large scale to remove the foul odor of cistern water. Potassium permanganate should be added to the water until, on mixing, there is a slight pink tint to the water.)

ANALYSIS OF CITY WATER SUPPLY [1]

(PARTS PER MILLION)

	Free Ammonia	Albuminoid Ammonia	Chlorin	N as Nitrites	N as Nitrates	Required Oxygen	Total Residue
Springfield, Mass., Aver. 1893	.009	.204	1.50	.001	.026	5.132	37.6
Boston, " " 1894	.006	.319	4.10	.001	.106	6.295	46.4
Burlington, Vt. (Lake Champlain)	.035	.140	0.70	0	trace	1.525	70.0
Poughkeepsie, N.Y. (Hudson R.)	.050	.125	4.50	trace	trace	2.287	85.0
Rock Island, Ill. (Miss. R.)	.025	.260	1.00	0	trace	6.000	140.0
New Orleans, La. (Miss. R.)	.040	.325	14.50	0	.080	5.724	340.0
Charleston, S.C. (artesian well)	.300	.040	130.00	.368	0	2.043	1170.0
Brooklyn, N.Y. (ground water)	.001	.085	13.50	0	16.000	—	64.0
Cincinnati, Ohio (Ohio R.)	.003	.108	14.00	—	.260	—	140.0
Philadelphia (Schuylkill R., average of 22)	.010	.100	—	0	.460	—	133.4
New York, weekly average for 1894	.012	.082	2.47	0	.258	—	81.6

DRINKING WATER AND DISEASE

It should be noticed in the first place that while peaty waters contain quite large quantities of organic matter, this is not considered as injurious as other kinds of organic material. The best authorities seem to agree, however, that its presence does tend to induce diarrhœa and malaria.

[1] "Water Supplies," Mason, 3d edition, p. 415.

According to recent investigations the prevalence of malaria in certain localities is found to be due to the low land and numerous puddles where the mosquitoes that transmit the infection have a chance to breed.[1] It should also be said that though a water of this class may be harmless at some stages of its history, at other stages it may be injurious on account of the decomposition that has taken place. Another water containing a large quantity of organic matter is the so-called sawdust water, which is obtained from wells sunk in " made " land in the vicinity of streams where sawmills have been located. This is, without doubt, injurious.

In regard to hard waters, the opinion seems to be predominant that the mortality is practically uninfluenced by hard or soft water.

In many localities, waters that are extremely turbid are used for domestic purposes, and it is evident that they are used without apparent serious injury, when we consider the population and the death rate in such cities as Cincinnati, Louisville, and St. Louis. The death rate was very much lowered after filtration of the water supply. This should be said, however, that while these waters are used with impunity by those who are accustomed to their use, strangers for a time are frequently seriously affected by the use of such waters.

A much more serious class of impurities is those which come from the introduction of sewage into the waters, and although they may be perfectly clear, transparent, and of good taste, such waters are often extremely dangerous. The question arises, Shall the water once polluted by sewage be used for human consumption? If there is danger in such use, What is its extent, and can such

[1] "Practical Hygiene," Harrington, p. 649.

danger be avoided? A few examples of pollution of water by sewage will be of interest.

In 1887 [1] the city of Messina, Sicily, was visited by an epidemic of cholera. From September 10 to October 25 there were 5000 cases and 2200 deaths. The government investigated this epidemic, and it was found that though the water which was supplied to the city left the gathering grounds in the mountain of good quality, part of it was diverted on its way to the city, and used by the washerwomen of the vicinity for washing clothes, and was afterward conducted back into the open canal which supplied the city. As soon as the authorities sent tank ships to the mainland and obtained pure water for use in the city, the plague ceased as if by magic.

In 1890 there were two violent epidemics of typhoid fever in the valley of the Tees in England. The country which supplied the water was not thickly populated, and the water was apparently good. It was found, however, that many of the towns discharged their sewage into the stream, and in dry weather the stream receded, leaving its banks dry and exposed. Here the filth accumulated, and in times of high water this was swept into the stream, and was afterward pumped into the reservoirs and used as the source of water supply. It was noticed that an "increase of rainfall was followed by an increase in the number of cases of typhoid fever among those persons using the Tees water, after an interval corresponding to the incubation period of the disease, while no appreciable result was noticed among those people of the district using other sources of supply." [2]

One of the most interesting cases is that of the city of Plymouth, Pennsylvania, containing 8000 population.

[1] Mason, "Water Supply," p. 24. [2] *Ibid.*, p. 27.

In a few weeks there were more than 1000 cases of typhoid fever and 100 deaths. The water supply was obtained from a mountain brook. There were but few houses on the banks of this brook, and it would seem that the water was well protected from sources of contamination. On investigation, it was learned that while the stream was frozen a man had been sick with typhoid fever, and had been cared for in a house near the source of this mountain brook. The discharges were thrown upon the snow, and when this melted in the spring the filth was swept into the stream. The inhabitants of the village of Plymouth were obliged to use this water for a time as their source of supply, instead of the Susquehanna River, so the *Bacillus typhosus* was pumped to all parts of the city. It was noticed that whole groups of families using well water escaped, while those using the city water were afflicted with typhoid fever. It was estimated that aside from the deaths that occurred, the money losses to this community in wages and care of the sick was over $100,000.

All are more or less familiar with the conditions at the time of the terrible outbreak of cholera in Hamburg, Germany, in 1892. The city had a population of 640,000. The epidemic lasted for about three months, and the total number of cholera cases was 17,000, with 50% mortality. Hamburg is close to the city of Altona; in fact, these two together with Wandsbeck are practically one city, but they obtain their water from different sources. Hamburg pumps water from the Elbe River, the intake being just south of the city. Altona pumps its water from the Elbe at a point about 8 miles below that at which the river receives the sewage of the three cities; but in the case of Altona the water which has received the sewage

from a population of 800,000 people was filtered with exceeding care before being delivered to the people. It was interesting to notice in this case that in some sections of the city, people supplied with the Hamburg water were afflicted with cholera, while those on the other side of the same street using the Altona water were not afflicted, and this immunity from cholera of those using the Altona water was noticeable all over the city.

The analysis of the Hamburg supply showed in parts per million : —

Free ammonia	1.065
Albuminoid ammonia	.293
Nitrates	26.430
Chlorin	472.000

The case of the outbreak of typhoid fever at Lausen, Switzerland, is also very instructive. The source of the epidemic was traced to an isolated farmhouse on the opposite side of the mountain, where three cases of the fever occurred. The brook which ran past the house was afterwards used for irrigating some meadows, and then filtered through the intervening mountain to a spring in Lausen, from which all the people, except those in six houses, obtained their water supply. In the six houses no cases of fever occurred, but scarcely any in the other houses escaped. By dissolving a large amount of salt in the water on the other side of the mountain, and observing the great increase of chlorin in the spring water, the source of the infection was traced, and to show how thoroughly the water was filtered, a quantity of flour was mixed with the brook water, and not a trace was found in the spring water at the village. This showed that filtration through the rocks and soil of the mountain did not remove the dangerous infection.

" Under ordinary conditions no multiplication of typhoid bacillus takes place in water even when a considerable amount of organic matter is present, but on the contrary a steady decline in numbers goes on. The history of typhoid epidemics tends to show that sewage pollution is to be feared chiefly when the sewage is fresh, and that the danger of infection diminishes with the lapse of time. In soil the duration of life of the typhoid bacillus is much longer than in water." [1]

In conclusion, then, any source of supply may be contaminated, and there is danger in the use of well waters, especially in crowded districts. Numerous diseases are distributed by impure waters, and, in any case of an epidemic of those diseases that are caused by specific bacteria, the water supply should be very carefully examined, and it is always advisable at such times to boil the water before using.[2]

[1] "Sewage Disposal," Fuller, p. 122.

[2] Consult for further details, "A Text Book of Hygiene," Rohe and Robin.

CHAPTER VI

PURIFICATION OF WATER SUPPLIES

NATURAL PURIFICATION

WATER is naturally purified by *sedimentation, dilution, oxidation, filtration, vegetable growth,* and *bacterial action.* The extent to which each of these agencies improves the water depends on a variety of circumstances. With the deposit of mud and silt there is often carried down a large amount of organic matter; indeed, the presence of a certain amount of suspended matter in some of the Western rivers seems to assist in the removal of organic impurities. Sedimentation as ordinarily practiced, however, will not purify an unsafe water.

Dilution of a small stream carrying sewage by a large stream of purer water seems to make it of better quality, but really the organic matter is simply distributed through a larger volume of water, and not necessarily destroyed.

Oxidation, by a rapid fall, or by exposure to the air in running over riffles, as in a shallow stream, has been depended upon formerly for a large amount of purification. There is a difference of opinion, however, as to the extent to which oxidation will destroy pathogenic germs. W. C. Young[1] states, as the result of his experiments, that the removal of dissolved organic matter from river water by natural means is extremely slow. The principal

[1] *Jour. Soc. Chem. Ind.*, Vol. 13, p. 318.

agent in this purification is the growth of vegetable organisms, and atmospheric oxidation has little effect. It has been recently shown that standing water, not running water, effects self-purification most rapidly.

ARTIFICIAL PURIFICATION

History

It is possible to purify water on a large scale under the control of a public water supply company much more economically and thoroughly than can be done by household filtration. Furthermore, the tests for purity and the control of the supply as a whole can be handled at comparatively small expense, for a large urban population.

On this account, following the methods inaugurated in Europe many years ago, the city of St. Louis attempted to improve its water supply as early as 1866, and in 1887 and the years following the Massachusetts State Board of Health carried on experiments for the purification of water and sewage in connection with the water supply of Lawrence, Massachusetts. It is notable that the filter here introduced was found to be very efficient and the use of the filtered water reduced the death rate from typhoid fever 79% in five years. Experiments made in Louisville, Kentucky, upon the Ohio River water resulted in the installation of a very complete filtration system. Other cities, as Washington, D.C.; New Orleans; Springfield, Massachusetts; Cincinnati; St. Louis, and Baltimore, have put in improved filter plants and furnish at the present time water of a high degree of purity from adjacent rivers. Either rapid sand or slow sand filters are now in use in all the large cities of the country where river water is utilized as a source of supply.

METHODS OF PURIFICATION

Water, to be safe and harmless for domestic use, must be practically free from all bacteria in order that the pathogenic bacteria may be completely removed. It should also be free from suspended matter, from odors and tastes that are disagreeable, from iron, and from color. If to be used for industrial purposes, water should be practically soft and of low mineral content.

The practical methods for purifying water are: —

(*a*) Coagulation and Sedimentation.
(*b*) Slow Sand Filtration.
(*c*) Rapid Sand or Mechanical Filtration.[1]
(*d*) Combinations of ($a + b$) or ($a + c$) or ($a + c + b$).

(*a*) *Coagulation and Sedimentation.*

Although sedimentation alone will greatly improve a water, yet we do not at the present time depend on this process. Coagulation with sedimentation has been used on the muddy streams of the Middle West with considerable success. The coagulants to be added to the water as it is drawn into the settling basins are ferrous sulfate, lime, and alum. Large settling basins, which will hold a supply for two or three days, are required. The coagulum carries down a large per cent of the bacteria contained in the water.

(*b*) *Slow Sand Filtration.*

This process, which is widely used on the Continent, is also used in treating the supplies of some of the larger cities in the United States. The water is first allowed to settle, sometimes with the use of a coagulant, and in this way a large percentage of the suspended ma-

[1] "Water Purification Plants and Their Operation," Stein, p. 21.

terial is removed. The settled water is then allowed to flow uniformly over a sand filter, which is made of clean quartz sand, three to four feet in depth, overlying a bed of gravel, graded to increase in coarseness towards the bottom. Open-jointed tile pipes serve to withdraw the water under the gravel. The best results are attained by allowing the water to flow through the filter at the rate of about 3,000,000 gallons per acre per day. After the filter is in operation, it will be found that a slimy gelatinous film forms on the surface and between the sand grains. This jelly is largely of bacterial origin, and helps very materially in holding back the silt and bacteria in the water.

When the filter becomes clogged, it is shut down and drained, and the surface is removed to the depth of one-half inch or more, with broad, flat shovels. The removed sand is afterwards washed in such a way as to take out all the slime and silt, and is again used in the filter. The efficiency of this variety of filter increases for some time after the filter is first installed, as the mat or slime of bacteria and organic matter increases in thickness. It is evident that the area of the filter beds must be large enough so that some beds can be cleaned while others are in use. As an illustration of the efficiency of this system of purification, it is noted that in the Altona case the average number of germs in the unfiltered water was 28,667 per cc. and in the filtered water only 90, so 99.67 % were removed. The removal of the bacteria is not due simply to the straining, but the conditions within the filter are unfavorable to the life of the bacteria. Since the food material for bacterial growth is gradually taken away, the water actually improves in quality as it flows through the service pipes to the consumer.

(*c*) *Rapid Sand or Mechanical Filtration.*

This is also best performed with the use of a coagulant. The water is purified so far as possible by sedimentation, as in the previous process, then mixed with the requisite quantity of the coagulant (alum, lime, or an iron salt), and, when the water is to be more completely softened, a solution of soda-ash is added. If the water is "temporarily hard," alum may be used in the treatment, as the calcium bicarbonate present will cause the precipitation of aluminum hydroxid.

The water is forced through a bed of sand contained in a tank, and when this sand becomes clogged, the water is turned off and a reverse current coming from below washes the sand for about fifteen minutes. In this process the silt and precipitate of iron or aluminum hydrate, being lighter, is carried over the partitions of the tank into the waste, while the sand continually settles to the bottom of the basin. After the sand is thoroughly cleansed, the unpurified water is again turned on. In this method of treatment the "bacterial jelly" of the slow sand filtration process is replaced by an artificial inorganic jelly or gelatinous precipitate which effectively entangles the bacteria and reduces the amount of organic matter in the water.

WATER-SOFTENING

The advantages of using a soft water have already been referred to (p. 78). It is possible to soften a water at the same time that it is filtered, and with a few modifications the mechanical filter plant can be used for this purpose. Larger sedimentation basins and facilities for mixing lime and soda-ash with the water must be provided.

In the Clark process of softening, the bicarbonate of calcium, magnesium, and iron, the substances which cause "temporary hardness," are precipitated by the addition of an excess of lime. This is in accordance with the following equation:—

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2\ CaCO_3 + 2\ H_2O.$$

The sulfates, chlorides, and nitrates of calcium and magnesium, which cause "permanent hardness" (p. 77), are precipitated by the addition of "soda-ash" (crude sodium carbonate) as follows: —

$$\left.\begin{matrix} CaSO_4 \\ CaCl_2 \\ Ca(NO_3)_2 \end{matrix}\right\} + Na_2Co_3 = \left\{\begin{matrix} Na_2SO_4 \\ 2\ NaCl + CaCO_3 \\ 2\ NaNO_3 \end{matrix}\right.$$

and in the case of magnesium salts: —

$$\left.\begin{matrix} MgSO_4 \\ MgCl_2 \\ Mg(NO_3)_2 \end{matrix}\right\} + Ca(OH)_2 = \left\{\begin{matrix} Na_2SO_4 \\ 2\ NaCl \\ 2\ NaNO_3 \end{matrix}\right\} + Mg(OH)_2.$$

It is not necessary or advisable to remove the mineral matters in a water by precipitation and filtration below 50–75 parts per million.

DISINFECTION

In some circumstances, as when it is not possible to completely purify the water by filtration, or when there is an unexpected demand upon the source of supply, or in case of accident to the purification plant, it is of advantage to have some means of protecting the users of the water from infection by the disease germs that may be present in the water. At one time copper sulfate and also potassium permanganate were recommended. Later ozone was tried, and found to be efficient in destroy-

ing bacteria, but its use was expensive. Ultra-violet light has also been recently used with success.

In 1908 hypochlorite of lime (bleaching powder) was tried and found to be a very satisfactory disinfectant at a low cost. At the present time chlorin, as bleaching powder or as liquid chlorin, has come to be very extensively used in city water supplies, because in its use there is such a gain in hygienic safety. Great care and skill are, however, required, lest disagreeable tastes and odors be produced by the use of an excess.

HOUSEHOLD PURIFICATION OF WATER

For those living in isolated houses, or where there is no public source of supply, it is often necessary to filter or otherwise purify the water before it is safe for domestic use. For *filtration* some device of porous stone or tile, or sand may be used. The filter should be of such construction that, if of stone, it can be readily cleaned with hot water and a stiff brush, or if of sand or similar porous material, by thoroughly washing. Filters made of unglazed porcelain, of the Pasteur-Chamberland type, or of diatomaceous earth like the Bekefeld filters,[1] have been shown to be extremely efficient, as practically all the bacteria in the water are removed by their use. In another style, plates of artificial stone are used as the filtering material. In all these filters the water, even if under pressure, percolates quite slowly through the material. Filters which are attached to a faucet and deliver the water rapidly are of little value to remove bacterial infection.

Boiling the water can always be depended upon to make a water safe, and this should always be resorted to in

[1] "Preventive Medicine and Hygiene," Rosenau, p. 793.

doubtful cases. It is only necessary to heat to boiling, or at most to boil for five minutes to destroy all pathogenic bacteria in the water. Boiling for twenty to thirty minutes may be necessary, should it be desired to fully sterilize the supply.

Bleaching powder and also ozone and ultra-violet light may also be used to purify a domestic supply, but these methods are not as convenient as those previously mentioned.

The good effect of *freezing* has been very much overestimated. Clear, transparent ice, from the surface of an open body of water, when melted, yields about 10% as many bacteria as were present in the original water. If a pond freezes solid to the bottom, all the impurities that were in the water will be in the ice.

Experiment 54. The action of a coagulant may be illustrated by putting a few grams of alum into a sample of water, and adding to it enough of a tincture of cochineal to give it a strong red color. Add to this ammonium hydroxid in excess, and allow to stand for some time, when the coloring matter will be precipitated *with the aluminum hydroxid*, $Al(OH)_3$, leaving the solution colorless.

In the iron process the water is brought in contact with spongy iron, and the result is the precipitation of ferric hydroxid, which carries down with it most of the organic matter. The precipitate may be removed either by sedimentation or by filtration through sand.

Experiment 55. To a dilute solution of ferric chlorid, add an excess of ammonium hydroxid. The reddish brown precipitate of ferric hydroxid produced is similar to that in the iron process.

Experiment 56. Pass a current of carbon dioxid through a dilute solution of calcium hydroxid till the precipitate at first

formed is dissolved. Add to this solution an excess of limewater and notice the formation of the precipitate.

WATER SUPPLIES OF CITIES

It has been estimated that the daily allowance of water for each person for all purposes is from twelve to fifteen gallons a day. Among the poorer classes a very much smaller amount is actually used, for cleanliness is expensive. In American cities, however, the amount of water used per day per capita is very much larger, as shown by statistics compiled from the pumping records. It must be remembered, however, that this includes all the water used for manufacturing purposes, for lawn sprinkling, etc., and especially does it include the very large amount of water wasted every day by carelessness and by leaky supply pipes. It has been found that the introduction of water meters very appreciably lowers the per capita consumption. In American cities the amount used varies from 33 gallons to 320 gallons.[1]

In each locality local conditions must determine what is the most practical and safest source of supply. Of the possible sources mentioned on page 72 the following have been utilized.

I. SURFACE WATER COLLECTED IN IMPOUNDING RESERVOIRS

The following cities, among others, are supplied in this way: New York City, supplied by the Croton River and the Catskill watershed; Boston, supplied by Lake Cochituate; Newark, and Jersey City, New Jersey; Worcester, Cambridge, Springfield, Gloucester, and Lynn,

[1] "A Text Book of Hygiene," Rohe and Robin, p. 47.

Massachusetts; New Haven, and Hartford, Connecticut; Altoona, Pennsylvania; Charleston, South Carolina; Norfolk, Virginia; Denver; San Francisco, and Oakland.

The catchment or collecting area, to be ideal, should be free from human habitation and covered with a forest growth. This is the case in respect to a few cities; ordinarily, however, there is a considerable population on the catchment area. Storage in these large reservoirs improves the quality of the water. Disease germs in our climate do not grow under these conditions and, if introduced, they are usually destroyed, because the length of time for which they can live under these conditions is limited, and the water is actually stored for quite a long time.[1]

II. WATER SUPPLIED BY SMALL LAKES

There are a few cities that are supplied in this way. These lakes are really natural instead of artificial impounding reservoirs for the surface water. Rochester, New York, is supplied in this way from Hemlock Lake, and Syracuse, New York, from Skaneateles Lake; Portland, Maine, from Sebago Lake; and St. Paul, Minnesota, from a number of small lakes.

III. WATER SUPPLIED FROM THE GREAT LAKES

The large cities supplied in this way are Chicago, Cleveland, Buffalo, Detroit, Milwaukee, and Duluth. The chief difficulty with this source of this supply is that these cities discharge their sewage into the lakes, and although large sums of money have been expended in driving tunnels under the bed of the lake to a point five miles or more distant from the shore for an intake, yet

[1] "Clean Water and How to Get It," Hazen, p. 13.

in certain conditions of weather and temperature it is almost impossible to keep some sewage from getting into the water supply.

IV. WATER SUPPLIED FROM RIVERS

On account of convenient transportation facilities there is a tendency in this country for those cities built on large rivers to increase rapidly in population. It often becomes necessary, however, to obtain the water supply from the same stream. In the United States the following large cities, among others, are supplied from rivers: [1]

Place	Population 1910	Water from What River	Drainage Area above Intake sq. miles
Philadelphia	1,549,008	Delaware	8,186
		Schuylkill	1,915
St. Louis	687,029	Mississippi	700,663
Pittsburgh	533,905	Allegheny	11,400
Cincinnati	363,591	Ohio	72,400
New Orleans	339,075	Mississippi	1,261,084
Washington	331,069	Potomac	11,476
Minneapolis	201,408	Mississippi	19,585
Kansas City, Mo.	248,381	Missouri	163,752
Indianapolis	233,650	White	1,820
Providence	224,326	Pawtuxet	—
Louisville	223,928	Ohio	91,000
Toledo	168,497	Maumee	6,723
Richmond	127,628	James	6,800
Paterson	125,600	Passaic	773
Omaha	124,096	Missouri	322,500
Nashville	110,364	Cumberland	12,800
Albany	100,253	Hudson	8,240

[1] "Clean Water and How to Get It," Hazen, p. 32.

If water of this kind must be used, it is necessary to install very complete purification works. If all cities were obliged by law to treat their sewage before they discharge it into the river, the problem of purification of a city supply would be very much simplified. It is, however, considered impractical to purify completely all the sewage entering into a stream, so a purification system for the water supply seems to be absolutely required.

V. GROUND WATER SUPPLY

In many localities, and especially for the smaller cities, ground water is the most available and safest source of supply. In Brooklyn, most of the water supply of 142,000,000 gallons daily is obtained from tubular wells driven in coarse ocean sand and gravel. In the vicinity of Brooklyn on Long Island and in New Jersey some other cities, notably Camden, New Jersey, are supplied in this way. Memphis, Tennessee, has been supplied in recent years by water drawn from sand and gravel deposits. Other cities that may be mentioned are Lowell, Massachusetts; San Antonio, Texas; Wichita and Topeka, Kansas; Jackson, Mississippi; and Winnipeg, Canada. Many European cities draw their water supply from wells. One of the most notable cases of this kind is Vienna, which has a population of 1,800,000.

One disadvantage of ground water is that in localities where there is a limestone soil these waters are hard; in granite regions or where there is an abundance of gravel near the surface, the water may be soft. Another disadvantage of ground water is that it frequently contains iron, which is removed by treatment and filtration, but with considerable difficulty.

Ground water should be stored in dark reservoirs, as under these conditions the algæ and other troublesome organisms, which injure the water, do not develop so rapidly. Surface water often improves in quality when stored in clean open reservoirs where the sides have been thoroughly cleared of vegetation. The effect of mud deposits in storage reservoirs is not necessarily harmful. If, however, these deposits furnish food for, and encourage the growth of, organisms that by their development impart a disagreeable taste and odor to the water, they should be removed.

CHAPTER VII

DISPOSAL OF SEWAGE AND GARBAGE

The organic and inorganic material that accumulates as the waste of the modern city or from the country dwelling is of such a character that it must be quickly removed or it is a menace to the health of the inhabitants. This material is handled by the municipality at the common expense of the community, or in the isolated house it must be handled by the individual. It naturally divides itself into two general classes: first, the fluid and semi-fluid refuse which is generally disposed of by the "water-carriage" system, that is, it is flushed out by an excess of water under the name of "sewage"; and second, the solid refuse which must be collected and carted to some central station to be disposed of and rendered innocuous. This is known as "garbage."

In the water-carriage system of sewerage two systems have been in use — the *combined* and the *separate*. In the combined system all excreta, kitchen slops, waste water from baths and manufacturing establishments, as well as storm water, are carried off in the same conduits. In the separate system the storm water is carried off by surface or underground drains not connected with the sewers, which only discharge the refuse from the toilets, factories, and houses. There is a growing opinion among sanitary engineers that the best results are obtained in the use of the separate system.

SEWAGE

Sewage may be defined as "a complex mixture, with water, of the waste products of life and industry from densely settled communities." The only solids of importance which this sewage carries are those which are susceptible of solution in water, or which become disintegrated in transit. Sewage consists very largely of water which acts as a vehicle to carry away a small quantity of other substances. In 1000 parts of sewage it is estimated that there is 1 part of mineral matter and 1 part of organic matter, leaving 998 parts of pure water. Now, the mineral matter contained in sewage is practically of no importance, so that all our efforts are directed toward the removal of the 1 part of organic matter in 1000 parts of water. The only really dangerous substances in sewage are the disease-producing organisms, but the gases given off as the result of decomposition are extremely disagreeable and will, if breathed continuously, no doubt lower the vitality. Sewer gas is not as liable to contain microörganisms, which will be injurious to the health, as was formerly supposed.

The material which issues from the sewers of large cities contains no dissolved oxygen and no oxidized nitrogen. The reason for this is that the available oxygen of the water has been removed in oxidizing a portion of the carbon of the organic matter, but it has not sufficed, also, for the oxidation of the nitrogen, and further oxidation can go on only by the addition of more oxygen to the water. If the nitrogenous material in the sewage is represented by ammonia, then the following equation may be written: —

$$2\ NH_3 + 4\ O_2 = 2\ HNO_3 + 2\ H_2O.$$

Now this nitric acid, coming in contact with the calcium carbonate of the soil and of the water, is decomposed thus: —

$$CaCO_3 + 2\,HNO_3 = Ca(NO_3)_2 + H_2O + CO_2.$$

The most modern theory for the treatment of sewage is that it is carried on very largely by bacteria, and even this process of nitrification, as it is called, which the above equation represents, cannot go on without the intervention of nitrifying bacteria. This class of organisms must work in a medium containing a sufficient quantity of free oxygen. This treatment may take place in water, when there is a sufficient quantity of the free oxygen in proportion to the filth handled. In soil this nitrification is of the utmost importance in the process of preparing it for the growth of plants, and in keeping up its fertility.

It [1] is not practical to purify sewage completely. Even in the most modern sewage treatment plants it often happens that the conditions are such that the effluent is very far below the standard for purified sewage. In other words, although the treatment removes a very large part of the foul putrescible matter that has an offensive smell and may remove a great proportion of the pathogenic germs, yet the purification cannot practically be carried far enough to render the effluent safe to use as a water supply. The water of the stream containing the treated sewage must itself be purified in a water-purification plant.

The sewage may be disposed of: —

1. By dilution.
2. By irrigation.
3. By intermittent filtration.
4. By chemical precipitation.

[1] Geo. C. Whipple, *Am. Jour. Pub. Health*, Vol. III, p. 516.

DISPOSAL OF SEWAGE BY DILUTION

If the stream into which the sewage is poured is small, and the current of low velocity, the result will be the production of a very disagreeable odor from the decomposition of the sewage, but if, on the other hand, the flow of the stream is large, this sewage will be distributed through so much water that we shall not find any offensive odor arising from it. It has been estimated that a stream which carries off sewage should have a volume of from twenty-five to thirty-five times that of the sewage; the proportion, however, depends on the amount of free oxygen that is carried by the stream and several other factors. The amount of water needed to carry off the sewage can be calculated readily, by knowing the amount of water supplied to the town, as it has been found under normal conditions that the volume of sewage is practically the same as the amount of water supplied.

In the case of the city of Milwaukee, as an illustration, for many years the sewage was turned into the Milwaukee River, a small stream, which became extremely foul, but arrangements were made to pump a large amount of water from the lake into the river $3\frac{1}{2}$ miles inland, thus supplying 26 times as much water as the volume of the sewage, and by so doing the sewage was flushed out with the water, and the odor disappeared. To handle the sewage of Chicago it would be necessary to follow the same plan, and have 25 times as much water in the drainage canal as the sewage of the city.

The objection to the disposal of sewage in this way is, of course, the rendering of a river water so impure. Although some experimenters have argued that water after running 20 miles is quite completely purified by

the process of oxidation and nitrification, others claim that, even by running ten times as far, the pathogenic germs would not be removed, and there is a natural repugnance against using, for drinking purposes, water that has been at any time contaminated by sewage unless it is purified by sand filtration.

BROAD IRRIGATION OR SEWAGE FARMING

Another method of disposal of sewage is by irrigation. There is a large amount of fertilizing material in the sewage of the modern city, and very persistent efforts have been made to utilize it economically. In America [1] this process has very little standing as an independent method of purifying sewage, especially in the more humid regions of the country. In Europe the process has been much more successful, but little financial profit has been made by sewage farming. The partial success abroad is no doubt due to favorable soil conditions, especially in Paris and Berlin, and to very careful and efficient management. In England broad irrigation is still practiced quite extensively, but in many locations it does not succeed. The objections to the method that have been raised are the disagreeable odors in the vicinity of the farms, prejudice against the growing of vegetables by the use of sewage, and the transmission of disease germs by flies and other insects.

INTERMITTENT FILTRATION

The next method for disposal of sewage is by intermittent filtration. This process is a natural one, because it depends for its success upon the prevalence of certain natural conditions; that is, the presence of oxygen and

[1] "Sewage Disposal," Fuller, p. 613.

living microörganisms. If we allow sewage to run, for some time, upon a filter bed composed of sand and gravel and then turn this sewage on to another filter bed and allow the water to run out of the first bed and the air to enter the spaces between the grains of sand, we furnish the conditions for the growth of the microörganisms. This is much more satisfactory than attempting to filter continuously through the same filter bed. As an illustration it was shown in one case that by the use of this process where 31,400 gal. of sewage per acre was filtered, 98.6% of the organic impurity was removed, and 99% of the bacteria.

THE SEPTIC TANK

There is a modification of the above method which is known as the use of the septic tank, in which the sewage is liquefied by being stored first in the sunshine or in the air, allowing the aërobic bacteria to work, and afterward in a closed tank where another class of bacteria (the anaërobic) carry on their purifying process. This material is then run upon filter beds, and a very pure effluent is the result. Some engineers prefer to run the sewage first into a closed tank, through which it requires from 12 to 24 hours to pass, and where a thick scum covers the surface, gases are given off, and very complete decomposition takes place. The effluent from this tank is then run on to filter beds. It is to be noted that both aërobic bacteria, or those which work in light and air, and anaërobic bacteria assist in the purification of sewage.

THE IMHOF TANK

The Imhof tank or Emscher-Brennen is another method of completing biological digestion of the solid

ingredients in sewage. The tank is in two compartments, the sewage flowing through an upper slotted trough at a rather slow rate, the solids settling out through the slots into the deep well below, where they are digested by anaërobic bacteria. The residual sludge is much smaller in volume than the sludge obtained from the septic tank; it is slow to purify and much more easily dried.

The Imhof tank or well has been adopted by Baltimore and Atlanta as preliminary treatment before going to biological filters. Many small towns are using it as a preliminary treatment of the sewage. It is more successful in general than the septic tank, as it removes more suspended matter from the sewage and gives an effluent easier to handle on the biological filter.

THE ACTIVATED SLUDGE PROCESS

The activated sludge process was developed by Fowler and his colleagues in England and consists essentially of blowing air, in finely divided bubbles, for several hours through raw sewage. This gives an opportunity for the aërobic, nitrifying bacteria to oxidize the putrescible solids and soluble material over to innocuous nitrogen compounds. This reaction will take place after a culture of the bacteria have been properly grown in what is known as activated sludge. (Activated sludge is the name given to the sludge that has been aërated for several days or until it contains nearly a pure culture of true aërobic nitrifying bacteria.) It is necessary, therefore, always to retain some of the sludge to start the treatment of each dosing of sewage.

Many experiments have been carried out on intermittent and continuous methods, using this process, and it has been finally proven that a continuous process can

be operated with satisfaction, giving almost perfect removal of putrescible solids and a very marked reduction of bacteria, the effluent being nonputrescible. Consequently, this is a complete method of sewage disposal.

For many years, chemists and engineers have been trying to devise a means of recovering the nitrogen in sewage on a commercial basis. As the activated sludge is extraordinarily high in nitrates, it is a feasible proposition to dry this sludge on a commercial basis and use it for a fertilizer. It has been shown at Milwaukee that it is probably possible to recover sufficient sludge to maintain the cost of running the sewage disposal plant.

DISINFECTION OF SEWAGE

Liquid chlorin and bleaching powder have been used to disinfect sewage where it was thought necessary to obtain an effluent not detrimental to the public health. Usually the liquid chlorin or bleaching powder is dosed into the sewage after it has been given some preliminary treatment. Ordinarily the effluent from biological tanks and filters is treated with about 3 parts per million of available chlorin. This destroys practically all the intestinal bacteria. In some instances raw sewage is treated with large quantities of free chlorin where sterilization is demanded, and no annoyance will be caused by introducing the sewage so treated into a body of water. This method is utilized along the Atlantic coast in the vicinity of oyster beds.

CHEMICAL PRECIPITATION OF SEWAGE

Another method for sewage disposal is by chemical precipitation. For this purpose such substances as ferrous sulfate, ferric sulfate, lime, or alum are used. It was

at first proposed to utilize the precipitated material as a fertilizer, and considerable money has been spent in preparing this material and extracting the water from it by pressure. This process, however, has not been found to be very satisfactory, and improvements must be carried still farther before this method for disposal of sewage will be extensively adopted.

To recapitulate, for the purification of sewage, we must depend largely upon the work of bacteria often in the presence of oxygen, and any plan which utilizes the work of these organisms to the greatest extent, and furnishes the most complete conditions, for work in this way, will be successful.

DISPOSAL OF HOUSEHOLD WASTE

A method for economically disposing of garbage or household waste has long perplexed the health authorities. Two conditions may be considered: that of disposing of it by the householder on the premises where it is produced, and that of having it handled by the city authorities.

Several methods have been used for disposal of refuse without removal from the premises. Among these the process of burning in the stove, range, or furnace, either with or without previous drying, is suggested. This is efficient and practical if the amount of such waste material is not too large, and if a good fire is maintained. In summer, when there is naturally a larger amount of refuse, and the fires are not kept burning so continuously, it is often difficult to handle garbage in this way.

A modification of the above method consists in having an enlargement of the smoke pipe of the stove at the elbow, and to introduce into this, through an opening

in the side, a perforated basket containing the garbage. The material soon becomes dry and is partially charred, and then may be taken out and put into the stove, where it is useful as fuel.

In some cities the plan of building brick or stone furnaces in the yard, for the sole purpose of burning rubbish, has been adopted with great success.

Another method of disposal is by burying in the soil, and as the decomposition takes place rapidly, if only a few inches of soil is placed over the material, no obnoxious odor arises to contaminate the air. When one hole is filled, it is covered and another is dug beside it; but these holes must not be too deep or too large.

MUNICIPAL REFUSE

If the city or village undertakes to dispose of the garbage, usually great expense is incurred, as the quantity is very large. For instance, in Manhattan alone the dry refuse amounts to 1,000,000 tons in a year, and the garbage is 175,000 tons per year.[1]

Disposing of garbage to farmers for feeding of stock or swine is not very practical. This involves a long haul of ill-smelling material through the streets, and is particularly objectionable if the material is not collected every day.

In some localities garbage is loaded on to scows, towed out to sea and dumped, but here the incoming tide may throw the decomposing material back on the shore.

There is a very valid objection to using garbage, even if the more perishable material is excluded, for filling in the so-called "made land," as decomposition will

[1] Price, "Handbook on Sanitation," p. 49.

continue for years in this soil, and the air of dwellings built upon it will be contaminated.

Municipal refuse may be classified as follows:[1] garbage and small animals, ashes, general rubbish and manure and street sweepings. A common method of treatment is the reduction method, in which the grease amounting to 2 to 4 per cent is extracted by boiling under pressure, with naphtha and the "tankage" is used as a "filler" for artificial fertilizers or for fuel. Incineration may also be used by addition of combustible refuse without other fuel. Since in garbage there is often present from 15 to 30 per cent of partially burned coal ashes, it has some value as a fuel. Incineration in a suitable furnace seems to be the only satisfactory way to dispose of most general rubbish. This is the process used in Seattle, Richmond, New York, Milwaukee, and other cities. The heat is used for steam-making purposes and the clinkers are valuable for filling vacant lots. In 1899, 81 communities in Great Britain were employing incineration as the chief means for disposal of refuse, and 76 of them turned the heat developed from the combustion of this refuse to some useful purpose, such as making steam to run electric lighting plants, for sewage pumping works, for grinding road material, and for use in the process of disinfection of clothing.[2] It is well to remember that such quickly decomposing material as garbage should be immediately removed under sanitary inspection, whether any financial profit comes to the city from its treatment or otherwise.

[1] Rudolph Hering, *Journal Am. Pub. Health Ass'n*, Sept. 1910.
[2] Harrington, "Practical Hygiene," p. 509.

CHAPTER VIII

TEXTILES

The textile industry makes use of a variety of raw materials, which ultimately are made into clothing, draperies, carpets, and rugs, as well as canvas, cordage, and similar products. These fibers are mainly of vegetable or animal origin.

Those of vegetable origin are cotton, flax (linen), ramie, hemp, jute, and raffia, all made from the stem, bark, or bast fibers; henequin or sisal, and manilla hemp used in making ropes and twine; and fruit fibers, as cocoanut fiber, used especially for making brushes and mats. To this list should be added artificial silks and the artificial "fibers" which are all originally of vegetable origin.

Those of animal origin are wool, hair, and silk.

Mineral fibers are only used for special purposes, as asbestos for the manufacture of fire-proof fabrics. Some others are spun glass, mineral wool, and silver cloth.

The fibers and the manufactured products are subjected to various complex processes of cleaning, bleaching, and dyeing, but nevertheless it is possible to distinguish the one from the other, both by microscopical and chemical methods.

COTTON

This consists, after purification, of nearly pure cellulose $(C_6H_{10}O_5)_n$. The raw fiber is mixed with and attached to

the seed in the pod or boll of the cotton plant. This seed is with difficulty separated from the cotton by the use of an ingenious mechanical contrivance called the cotton gin. The seeds have recently become of great commercial importance on account of the oil which they contain, and the cottonseed meal which is used as cattle food. (See p. 275.) The cotton fibers, when examined with a microscope, consist of long flattened tubes, thicker at the edges than the center, and spirally twisted. These fibers are usually not over an inch in length. The twisted structure not only assists in the identification, but it greatly facilitates spinning, as the fibers more readily interlock to form a thread.

Experiment 57. Examine some cotton fibers by the use of a microscope magnifying from 150 to 300 diameters. A few fibers should be placed on the glass slide with a drop of water, and the cover glass carefully placed over them in such a way as to entirely exclude any air.[1]

Mercerized cotton is prepared as follows: The cotton is stretched on a frame and treated with a 30 % solution of sodium hydroxid, and afterwards well washed with water. By applying the soda solution to the *stretched* material, shrinkage, which would otherwise be about one fourth in length, is prevented, and at the same time the fibers are untwisted and acquire a high luster. The product is supposed to be a hydrated cellulose. Mercerized cotton is stronger than the untreated material, and takes hold of dyes more readily.

Experiment 58. Test the action of alkalies on cotton by boiling for a few minutes some cotton goods in dilute sodium hydroxid solution. After cooling dip the goods in dilute acetic

[1] Woolman and McGowan, p. 279.

acid and wash again. Compare the strength and appearance of this sample with another sample which has not been treated. Compare also experiments under Cellulose (p. 172).

FLAX (Linen)

The source of linen is the bast or inner bark fibers of the flax plant. The stalks, after being cut and stripped of their tops, seeds, and leaves, are laid in bundles in a pond where a fermentation process known as "retting" takes place. Under these conditions the water dissolves the connective tissue and soluble substances, and leaves the flax fibers. By a slower process the bundles of flax are spread on the grass and exposed to the action of the air, sunshine, and dew for a longer period. After the retting the fibers are subjected to mechanical processes known as "breaking" and "scutching," in which the woody parts of the stem are removed, leaving the clean fiber. The long fibers, known as the "line," are also separated from the shorter fibers, known as "tow." (The flax may or may not be bleached before spinning into threads.)

The linen fibers are of quite different structure from those of cotton. They are long cylindrical fibers tapering to a point. Fine cross lines appear at intervals which give the appearance of joints or nodes. The fiber cells are pointed at the ends and polygonal in cross section.

Experiment 59. Examine some linen fibers on a glass slide with a good microscope and compare with cotton fibers. Treat with iodine and again examine.

Experiment 60. After freeing a sample of linen from dressing by boiling with a 3% hydrochloric acid solution, treat with a 1% sodium carbonate solution, rinse with distilled water, and dry. Moisten the fringe on two adjacent edges, as obtained

at a corner of the goods with olive oil or glycerine. Press between filter paper and place against a dark background. Notice that with this treatment the linen fibers appear translucent, while cotton fibers, if present, appear opaque and white.

WOOL

The hair of the sheep, goat, or similar animal is of entirely different structure from those already described. This hair really consists of three distinct portions,[1] — the *medulla*, a central marrow, frequently containing the coloring matter of the wool; the fibrous *cortical* tissue, which gives the material most of its strength and elasticity; and the *epidermis* of horny scales, which appear to be flattened cells overlapping one another like shingles. To the latter structure is due the characteristic "felting" property of wool. Different animals yield fibers of various length and thickness, and on their characteristics much of the different values depend. Ordinary wool fibers are from one to eight inches in length and $\frac{1}{500}$ to $\frac{1}{3000}$ of an inch in diameter. Raw wool contains frequently as much as 70% of impurities. These consist of "wool grease," "suint" or dried perspiration, mostly a potassium soap, vegetable and mineral dirt. These impurities are removed from the wool by washing with a solution of sodium carbonate. After "carbonizing" to remove the vegetable matter, the wool is treated by the mechanical operations of carding, spinning, and weaving.

Experiment 61. Examine some woolen fibers on the glass slide with a microscope.

Experiment 62. In two porcelain evaporating dishes test samples of wool and of cotton by immersing them for 15 minutes in concentrated sulfuric acid and in a 10% caustic soda

[1] "Household Chemistry," Snell, p. 219.

solution. Remove the residue, wash, and examine. The sulfuric acid, while it dissolves cotton, causes the wool to become jellylike. With caustic soda the wool is dissolved and the cotton remains unchanged.

SILK

Silk is obtained from the cocoons of a caterpillar which feeds on the leaves of the mulberry tree. It differs from the other fibers described in having no cellular structure. The viscous fluid called fibrosin secreted by the glands of the caterpillar exudes in two streams which are afterwards united by a substance called sericin which is also secreted by the caterpillar. Under the microscope these two threads with their connecting masses are seen. These threads are from .0005 to .0007 inch in diameter and from 1300 to 1400 yards in length. About 75% of the weight of the raw silk is fibrosin or silk fiber proper and is separated by washing from the sericin which accompanies it.

Experiment 63. Examine a sample of raw silk on the slide under a microscope.

Experiment 64. If silk (white silk thread) is treated with a 40% solution of hydrochloric acid for two minutes, the silk is dissolved.

ARTIFICIAL SILKS (Viscose)

These products are made from some form of cellulose and are therefore originally of vegetable origin. For making *pyroxylin silk*, or *Chardonnet silk*, pure cellulose is converted into *nitro-cellulose* (see p. 171), and this is dissolved in ether and alcohol, making *collodion*. This pasty mass is then forced by great pressure through very small openings in a metallic plate into a warm chamber. The ether and alcohol soon evaporate and are recovered

and used again as a solvent. The threads can be rolled on bobbins, but must be "denitrated" by immersing in a solution of sodium sulfid or ammonium sulfid. This takes away the highly inflammable quality of the nitrocellulose, and the threads are ready for use.

For making the cuprammonium silk, by Pauly's process, the cellulose is dissolved in an ammoniacal solution of copper hydroxid, and this is treated as in the previous process. This product is extensively used in Germany.

In the *viscose* process, wood pulp is treated with a strong solution of caustic soda, and the soda-cellulose so formed is treated with carbon bisulfid. The product thus obtained, although soluble in water, is insoluble in alcohol and in brine. The viscous solution is forced through fine openings into a solution of common salt, which precipitates the material in fine threads. This viscose is decomposed by heat or by an ammonium chlorid solution into cellulose, which may be spun and dyed like silk.

Experiment 65. Boil a sample of white artificial silk with a 4% solution of caustic potash, and it will be seen that the solution turns yellow. Pure silk treated in the same way leaves a colorless solution. Millon's reagent [1] also turns genuine silk red, while artificial silk is uncolored.

Experiment 66. *A Comparison of Textile Fibers.* Burn a few threads of cotton, linen, wool, silk, and artificial silk and notice the difference in behavior. Vegetable fibers flash up and burn quickly, while the animal fibers burn slowly. Notice also the odor.

Experiment 67. Ignite some of each of the fibers in a dry test tube. Notice the odor of the fumes which is characteristic.

[1] To prepare Millon's reagent, dissolve 100 grams of mercury in 71.5 cc. of strong (1.4 sp. gr.) nitric acid in the cold. When chemical action ceases, add twice the volume of cold water.

Red litmus paper moistened and held in the fumes will be colored blue if ammonia is given off, as when animal substances burn. A paper dipped in lead acetate will be colored brown by the fumes of hydrogen sulfid, when wool is heated in this way. With cotton or linen the fumes should color blue litmus paper red from the volatile acetic acid formed by the distillation. With fabrics consisting of mixed fibers, the results of the above experiments are liable to be misleading.

Experiment 68. To distinguish between wool and cotton, use white fabrics or threads of each. Place in porcelain dishes with Millon's reagent, and heat gently. It will be noticed that the vegetable fibers are unchanged in color, while the animal fibers become red.

Experiment 69. Since linen is often adulterated with cotton, it is important to distinguish between these fibers. Use a fringed or frayed sample of the material, so as to get both the warp and woof. Place this in a porcelain dish and heat gently for two minutes in a 50% solution of caustic potash. Remove with a glass rod, wash, and dry between filter papers. The linen will be dark yellow in color and the cotton white or light yellow.[1]

In general it should be noted that with acids and alkalies the following reactions take place:[2] —

Reactions with Alkalies

	Wool	Silk	Linen	Cotton
Strong caustic alkalies	Destroyed	Destroyed less rapidly	Fiber swells, becomes brownish yellow	Fiber swells, pale yellow
Boiling 5 per cent NaOH or KOH	Destroyed in 5 min.	Destroyed less rapidly	Little effect if air is excluded	Same as linen
Cold 10 per cent NH_4OH or $(NH_4)_2CO_3$	Little effect	Little effect	No effect	No effect

[1] Adapted from Woolman and McGowan, pp. 296–297.
[2] "Shelter and Clothing," Kinne and Cooley, p. 197.

REACTIONS WITH ACIDS

	WOOL	SILK	LINEN	COTTON
Conc. H_2SO_4	Succumbs slowly on heating or drying on fiber	Destroyed with yellow color in 2 min.	Soon dissolves	Dissolves more quickly than linen
Strong HNO_3	Becomes yellow (xanthoproteic reaction). Dissolves slowly	Same color effect as wool; dissolves quickly	Not colored; dissolves slowly in hot solution; nitrates in cold	Same as linen
Strong HCl	Hardly affected	25 per cent solution contracts fiber; 30 per cent dissolves in 10 min.; 40 per cent dissolves in 2 min.	Dissolved very slowly by concentration	Action quicker than with linen
Picric acid	Yellow	Yellow		

The problem of differentiating between various textile fibers is much complicated by the various processes to which the goods are subjected in preparing them for the market. These include bleaching, especially with sulfur dioxid and chlorin; dyeing, with a great variety of colors, both of vegetable origin and those made from coal tar; weighting, a process applied especially to silks which not only adds greatly to the weight of the goods, but loads them with numerous chemicals; dressing and sizing with starch, glue, dextrin, etc., and finally finishing.

FIRE-PROOFING COTTON

After long investigation William H. Perkin, an Englishman, has succeeded in devising a process for rendering cotton fire-proof. This process was patented in the United

States in 1907. It is especially valuable for use on cotton-flannel and flannelette, and fabrics of that class, which, on account of the raised nap, are exceedingly inflammable. The material is first run through a solution of sodium stannate, of 1.22 sp. gr., so as to become thoroughly impregnated, and the excess of this solution is squeezed out. It is then dried by passing over heated copper drums, and afterwards run through a solution of ammonium sulfate of 1.75 sp. gr., again squeezed and dried. The soluble sodium sulfate which remains in the goods is then washed out, the material is dried and finished by ordinary methods. This very valuable process should be used more commonly for children's clothing, and in any case where there is danger that clothing may take fire.

For further details on textiles, or for methods of quantitative textile analysis, the student is referred to Bulletin No. 9, Department of Agriculture; "Textile Fibers," Matthews; "Textiles," Woolman and McGowan; "Shelter and Clothing," Kinne and Cooley; "Elementary Household Chemistry," Snell; "Chemistry of Familiar Things," Sadtler; "Municipal Chemistry," Baskerville; "Chemistry of the Home," Weed; "Chemistry of Common Things," Brownlee; "The Story of Textiles," Walton; "Laboratory Manual of Dyeing and Textiles," Matthews; "Textiles," A. F. Barker; and "Household Textiles," Gibbs.

CHAPTER IX

CLEANING: SOAP, BLUING, BLEACHING

With our modern knowledge of the means of transmitting disease, filth is something to be avoided, as it assists in the spread of infection from one locality to another. The love of cleanliness, which is considered a sign of a higher civilization, is, no doubt, the outgrowth of years of experience with the dangers of dirt. This abhorrence for filth is a sanitary safeguard: it protects the body, the air, the water supply, and the food supply. As man has advanced he has demanded some cleansing agent for the body, the utensils, and the clothing, and so great industries have developed for the preparation of these agents.

Substances used for cleaning act either mechanically or chemically to remove the offensive materials. In the use of soap and sand, for scouring, there is a combination of these methods; and, in fact, when the chemical loosens up the fibers or sets free the dirt, some mechanical process is often required to remove it.

Most of the polishing and **cleaning powders** on the market depend, for their efficiency, upon the action of a very finely divided substance like silica, precipitated chalk, or rouge. This is mixed with some fat or oil; thus, some " Putz Pomades " contain rouge, finely divided silica, and a perfumed fat. In the choice of a polishing

material, one should be selected that is so finely divided that it will not scratch the metal. Dry sodium bicarbonate (baking soda) can be safely used for cleaning and polishing. Rejected Welsbach mantles are also well adapted for this purpose.

To remove a stain, the process selected depends on the character of the stain. It may be *dissolved*, *absorbed*, *bleached*, or *neutralized*.

Borax, $Na_2B_4O_7$, added to water, greatly aids in the removal of dirt, in special cases. Ammonium hydroxid (aqua ammonia) is also used for the same purpose, and, as it forms a soap with the oily matters of the skin or of the fabrics washed, it is a convenient cleaning agent. A teaspoonful of ammonia to a quart of water is an excellent wash for woodwork, and may be used to brighten carpets or rugs. Much of the "household ammonia" on the market is of a very low grade, and so it is always advisable to purchase ammonia from a druggist.

A cleaning material should not only remove the **grease** or dirt, but it must be of such a nature that it will not injure the article cleaned. From the work of Mrs. Richards,[1] many of the following suggestions are taken.

In some cases, as with wood, leather, metal, etc., the dirt does not penetrate into the interior, but remains on the surface; in other cases the whole fabric is filled with dust and grease. All polished wood surfaces, except those finished with wax, may be cleaned with a weak solution of ammonia, or soap, but they should never be treated with a strong alkali.

As **solvents for grease**, either kerosene or turpentine may be used, and should be applied with a soft cloth. Painted surfaces, especially if white, may be cleaned with

[1] Richards and Elliott, "The Chemistry of Cooking and Cleaning."

a little "whiting," $CaCO_3$, which can be applied with a piece of cheesecloth. The wood is afterward washed with water and wiped dry. Painted walls, if painted with oil paints, can be cleaned in the same way, but "tinted" walls, since water colors are used, are disfigured by this treatment.

Leather may be kept bright and clean by the use of kerosene, or occasionally a little oil. **Marble** may be scoured with sand soap, and finally polished with a coarse flannel. It should not be forgotten that marble is calcium carbonate, $CaCO_3$, and consequently should never be treated with an acid, or even an acid fruit juice like lemon juice. **Metals** can usually be cleaned with a hot alkaline solution or a little kerosene. To clean **glass**, it may be covered with a paste of whiting, ammonia, and water, and after it is dry this may be rubbed off with a woolen cloth or with paper. Kerosene is excellent for this purpose, especially in the winter when the water would freeze.

Household fabrics are often washed with alkaline solutions or with soap. In some cases naphtha may be used for washing such fabrics. As some of the solvents, such as naphtha, benzine, turpentine, and gasoline are frequently used for cleaning, and removing grease, it is extremely important to remember that they are all very volatile, and that the vapors may take fire from a lamp, gas jet, or stove, even if at some distance. On this account work of this kind should be done by daylight and out of doors, if possible. Many serious burns occur from lack of these precautions. *Carbon tetrachlorid* (CCl_4) has been recently used in the place of benzine, and has the advantage of being incombustible, and of being nearly odorless. It may also be used to mix with gasoline. In

the use of the volatile solvents like gasoline, enough should be used to cover a large portion of the goods.

To remove stains, spots, and tarnish, a little knowledge of chemistry will serve an excellent purpose. Since grease is readily absorbed by blotting paper, spots may often be removed from fabrics by placing the goods between two pieces of blotting paper, and then heating with a warm iron. French chalk will sometimes absorb the grease, especially if the spots are fresh. Grease may also be removed by the use of hot water and soap, ammonia, or even borax. If there is danger that these solvents will injure the goods or the colors, it is better to use some solvent such as chloroform, ether, alcohol, turpentine, benzine, or naphtha. Ether and chloroform are better adapted to the more delicate fabrics. "The troublesome 'dust spot' has usually a neglected grease spot for its foundation. After the grease is dissolved, the dust must be cleaned out by thorough rinsing with fresh liquid or by brushing after the spot is dry." [1]

Since **paints** consist of oil and some coloring matter and lead or zinc oxids, paint spots should be treated with a solvent for the oil, and then the coloring matter can be brushed off. Fresh spots may be treated with turpentine, benzine, naphtha, or gasoline, but old paint spots must be softened with oil or grease, and may then be removed by the appropriate solvent. Pitch, tar, or varnish may be treated with oil, and then be dissolved out with turpentine. Paraffin is most readily removed from clothing by putting blotting paper over the spot and melting it with a hot iron. The paper will absorb the melted paraffin.

Sugar deposits are soluble in warm water. If acids have

[1] Richards and Elliott, *loc. cit.*

destroyed the color of goods, this may usually be restored by ammonia, and dilute alcohol may sometimes be used in the same way for the stains from fruit.

Ink spots would not be so difficult to remove if we knew in advance the composition of the ink. Fresh ink usually dissolves in cold water, though sometimes sour milk or lemon juice is more efficient. Ink stains may also be removed with blotting paper or some absorbent. Ink stains on marble may be treated with turpentine, baking soda, or strong alkalies, or a paste may be made with the alkali and turpentine, and this may be left for some time in contact with the spot, and finally washed off with water. A dilute solution of oxalic acid may often be successfully used to remove either ink stains or iron-rust spots.

If there is much **iron** in the water supply, this stain may be removed from bowls or other porcelain ware by the use of hydrochloric acid, then rinse with water, and finally with a solution of soda. The addition of one per cent of formaldehyde very greatly reduces the action of the acid on iron pipes.

Silver is readily tarnished by sulfur, either from eggs, or from rubber bands or elastic, or sometimes from the sulfur compounds in the illuminating gas. The sulfid of silver thus formed is grayish to black. Silver thus tarnished should be rubbed with moist common salt before washing, thus forming a silver chlorid, which is then washed in ammonia, in which it is soluble. Another common method of cleaning silver is to boil the silver ware in a porcelain-lined kettle with a piece of sheet aluminum, and a little soda and salt. The articles are then rubbed slightly with a soft cloth.

For cleaning and polishing **brass** and **copper**, nothing is better than oil and rotten-stone, and most of the good

polishes on the market are made from these materials, with alcohol, turpentine, or soap. Kerosene is useful in keeping metals bright, as well as glass and wood. Aluminum may be cleaned by the use of whiting or any silver polish, but alkalies *should not be used* upon this metal. Aluminum does not readily tarnish. As it does not rust, with ordinary care it will, in a kitchen utensil, last for many years. **Iron-rust stains** may often be completely removed from delicate fabrics by the use of lemon juice and common salt.

Experiment 70. To remove an iron-rust spot from a piece of goods, stretch the cloth over a dish containing hot water, then as the steam arises and the goods becomes moist, drop a little muriatic acid, HCl, upon the rust spot with a medicine dropper; after a moment lower it into the water. If the spot is not removed, repeat the operation, then rinse in clear water, and finally in a dilute solution of ammonia to neutralize any acid that might remain and injure the goods.[1]

SOAP

Water, and a few other solvents, are used to remove dirt, or, as it is sometimes called, "matter out of place." Some of these foreign substances readily dissolve in the water; others, like the fats, will dissolve in ether or gasoline; and still others, as the resins, will dissolve in alcohol. Some form of alkali, such as wood ashes, was formerly used with the water, to assist in removing the dirt. It was found, however, that this had a very destructive action on the goods, so a "saponified" fat, the product produced by the action of an alkali on a fat, or what we call soap, came into use. This, when well made, does not injure the goods. Soap was used instead of the lye from

[1] Richards and Elliott.

the lixiviation of ashes, long before the chemistry of the process became known. It was not till 1813 that Chevreul published his scientific researches on the composition of fats and the process of soap-making.

The raw materials used in soap manufacture are a fat and an alkali known as " caustic alkali," which may be either sodium hydroxid (NaOH), which makes a hard soap, or potassium hydroxid (KOH), which makes a soft soap. These are made by boiling the carbonate with slaked lime, in accordance with the equation: —

$$Na_2CO_3 + Ca(OH)_2 = CaCO_3 + 2\ NaOH.$$

From this mixture the calcium carbonate settles out, and the solution of the caustic alkali is boiled down to a solid, and is put upon the market under the name of " concentrated lye," or the concentrated solution is used directly by the soap maker.

More recently caustic soda has been made directly by the electrolysis of sodium chlorid, NaCl. The sodium deposited at one pole is dissolved in water, and the chlorin is used for making bleaching powder.

The other ingredient of a soap is either a vegetable or animal fat or oil or a resin. Such oils as that of palm nut, cocoanut, olive, hemp seed, linseed, cottonseed, fish, or lard may be used, and fats like beef tallow, mutton tallow, lard, or house grease.

SAPONIFICATION

The process of " saponification " may be brought about either by the action of water or steam at high temperature and pressure (especially in the presence of a dilute mineral acid), by the action of caustic alkalies, or sometimes by the use of lime (see Candles, p. 56).

The fats may be briefly described as consisting of ethers of the triatomic alcohol-radicle, containing glycyl, C_3H_5. By treatment with alkalies or high-pressure steam, they yield glycyl alcohol (glycerin) and stearic or other fatty acid.[1]

The name given to the compound of the acid and glycerin is stearin, palmitin, or olein. In the case of stearin, the saponification equation would be: —

$$\underset{\text{Stearin}}{C_3H_5(C_{18}H_{35}O_2)_3} + 3\ \underset{\text{Caustic Potash}}{KOH} = \underset{\text{Glycerin}}{C_3H_5(OH)_3} + 3\ \underset{\text{Soap}}{KC_{18}H_{35}O_2}.$$

With palmitin or olein, the reaction is similar. If the fat or oil is solid, it contains a preponderance of stearin or palmitin, but, if liquid, there is an excess of olein.

In making soap on a large scale,[2] a kettle, provided with both a closed and open steam coil, so that the soap may be boiled either by the heat or the free steam, is used. A kettle that will hold 100,000 lb. of soap is 15 ft. in diameter and 21 ft. high, and is made of $\frac{3}{8}$ in. boiler plate. The melted fat and lye are run into the kettle and mixed by the aid of free steam and boiled for some time, or until the soap has a dry, firm feel between the fingers; it is then "salted out" by adding common salt. In boiling, the saponification represented in the above equation has taken place, and when salt is added this causes the soap to separate from the caustic lye and glycerin. After boiling, to mix thoroughly, the mass is allowed to stand in the kettle until the soap rises to the top, and then the lye may be drawn off at the bottom of the kettle. Some more strong lye is then added, and the boiling is continued till the material is fully saponified, which the experi-

[1] Allen, "Commercial Organic Analysis," p. 183.

[2] Thorp, "Outlines of Industrial Chemistry," p. 340.

enced soap boiler knows by sight, feel, and taste, and then the contents of the kettle is again allowed to stand for a while, and the additional lye is drawn off. The soap is then boiled with some water, and is allowed to settle again, to facilitate the separation of more alkali, dirt, and impurities, called "nigre." After standing several days, the soap is pumped into the "crutcher," which consists of a broad, vertical screw working within a cylinder, which is placed in a larger tank. Here it is thoroughly mixed, and any perfume or scouring material may be added. The soap is then drawn off into rectangular "frames," holding about 1000 lb., where it is allowed to solidify. The sides of these frames are removed and the soap is cut, by means of a wire, into slabs and then into bars. If put on the market in the form of cakes, the bars are afterwards pressed into the desired shape.

"Half-boiled" soaps are made in the "crutcher," by heating the stock to 160° F., and allowing it to stand for some time. It is evident that all the glycerin remains in a soap of this character.[1]

For making white soaps, tallow, palm oil, and cocoanut oil are used. **Castile soap**, if genuine, is made from olive oil, sometimes with the addition of cocoanut or rape seed oil. It is useless to attempt to make a good soap out of inferior material. In making lower grades of soap, cheaper fats are used, and frequently those that have a rancid odor. This is sometimes "corrected" by the addition of a strong perfume, like oil of "mirbane," — nitrobenzene, made from coal tar. **Yellow soaps** almost always contain considerable rosin; that is, they are made by the usual process, except that quite a large proportion of rosin is used to replace the fat. This has valuable

[1] "Industrial Chemistry," Rogers-Aubert, p. 575.

soap-making qualities, and would not be classified as an adulterant of soap. Cocoanut oil saponifies without boiling, so it is used in making the "cold process" soap. This material also admits of the use of a larger quantity of water, so that the soap will be hard and still contain as much as 70% of water. Soap is **mottled** by stirring into it, while warm, some coloring substance, such as copperas, ultramarine, or an aniline color. This does not in any way improve its quality.

Sand soap, pumice soap, and products of a similar character are made by incorporating sand, "volcanic ash," or powdered pumice, with the ground soap. These substances can act only mechanically; that is, they sandpaper off the dirt. Some of the most widely advertised cleaners consist of from 50 to 90% of "volcanic ash" or powdered feldspar, mixed with some powdered soap and alkali. A silicated soap is made by mixing with the ordinary soap some silicate of soda or soluble glass, as it is called. Into most laundry soaps both sodium silicate and sodium carbonate are "crutched," as a filler to soften hard water and to give additional detergent properties.

Toilet soap is made either by melting raw soap, by perfuming an odorless soap, after cutting in fine shavings and drying, or by making the soap directly by the use of pure materials. In either case the mass is colored by metallic oxides or aniline colors, and is perfumed by the use of essential oils, and then it is pressed into molds while yet fresh. Recent tests show that good toilet soaps that are made by some of the standard manufacturers cost the purchaser from 20 to 30 cents per pound for the actual soap bought. Fancy brands, especially those which are imported, cost from 50 cents to $1.40 per pound.

"Floating soap" is made by simply running the "crutcher" at a high rate of speed, thus entangling considerable air with the soap, and so lowering the specific gravity of the mass until it floats.

The use of a large proportion of cocoanut oil in soap facilitates saponification and tends to make a soap that can be used with salty water without curdling. Some "marine" soaps are made in this way, also shaving soaps.

To make a **transparent soap** it is necessary to dissolve an ordinary soap in alcohol, allow the insoluble residue to settle out, and distill the alcoholic solution to jelly. This may then be pressed into molds and dried. Another method very frequently employed is to make a cold process soap, with coloring matter and perfume added, and then to add to the mass more glycerin, or a strong sugar solution, which renders it still more transparent.

Soft soap is made directly by the use of potash lye, or by the use of soda lye and considerable water. The glycerin and the excess of lye, if any, remain in the soft soap. This is used in "fulling" or shrinking cloth and in other manufacturing operations, probably on account of the excess of alkali which it contains.

GLYCERIN

The salt lye which is drawn off from the kettle in which soap is boiled is used for the manufacture of glycerin. In this process the soluble soap and impurities are taken out by chemical treatment, and mineral salts are separated by evaporation and crystallization. The purified crude residue containing about 80% glycerin is distilled with steam under diminished pressure.

It is not economy to use a cheap soap, as on account of the excess of alkali which it usually contains it injures the fabrics washed, by causing the fibers to disintegrate and readily fall apart.

There is a great advantage in using a well-dried soap, as it does not so readily become soft in the water and therefore does not wash away so quickly. A laundry soap will lose 25 % of water if the bars are piled and allowed to remain for some time where they are freely exposed to the air.

In his researches on soap, Chevreul said that the cleaning action was because the soap was decomposed, when brought in contact with water, into fatty acid and alkali. The impurities are set free by the alkali and entangled by the fat acid salts, and thus removed with the lather. Thus it will be seen that vigorous rubbing is not necessary to remove the dirt, though, of course, it aids the process.

Ordinary soaps are readily soluble in water, but if the water is " hard " from the presence of lime or similar mineral substances, the alkali soap is decomposed and an insoluble lime soap is precipitated, thus forming a disagreeable scum on the water. Not until all this lime is thrown down by the soap will the latter begin to have a detergent action.

The equation for the formation of the lime soap would be: —

$$2\ C_{18}H_{35}O_2Na + CaSO_4 = Ca(C_{18}H_{35}O_2)_2 + Na_2SO_4.$$

On account of the necessity for using hard water in some localities " washing soda " $Na_2CO_2 + 10\ H_2O$ is used to " break " the water; that is, to precipitate the lime so that less soap will be required, thus: —

$$CaH_2(CO_3)_2 + Na_2CO_3 = CaCO_3 + 2\ NaHCO_3.$$

(See Hard water, p. 77.)

In order to make a laundry soap fit for use with hard water, sodium carbonate is added to it in the crutching.

Experiment 71. To make a hard soap, dissolve in a medium-sized beaker 15 grams of caustic soda (sticks) in 120 cc. of water, and pour one half of this into a porcelain evaporating dish of at least 500 cc. capacity; add 60 cc. of water and 50 grams of tallow. Boil this solution for three quarters of an hour, carefully replacing, from time to time, the water that has been lost by evaporation; then add the remainder of the solution of caustic soda and boil for at least an hour more. Water should be added as before, but the volume of the liquid may be allowed to decrease about one third. Add 20 grams of salt, boil for a few minutes, and allow the liquid to cool. The soap will rise to the top, and the glycerin, excess of lye, and salt will remain in solution.

Experiment 72. *Slightly* acidify the water solution separated from the soap in the above experiment with dilute hydrochloric acid. If any fatty acids or impurities separate out, filter. Pour the solution into a porcelain evaporating dish, and evaporate to dryness on a water bath. Dissolve the residue in strong alcohol, filter or decant from the undissolved crystals of salt, and evaporate the alcohol. The slight residue will be sticky, and give the sweet taste of *glycerin*.

Experiment 73. Cut a good quality of soap into shavings and mix with hot water on a water bath, until well dissolved. Add dilute sulfuric acid until the solution is acid. Note that if the soap is "filled," the sodium carbonate will cause an effervescence on adding acid. Heat on the water bath for some time or boil slowly, and the *fatty acid* will separate, forming an oily layer on the top. When clear this may be separated from the water by pouring on a wet filter, and the sulfuric acid removed from it by washing on the filter with hot water.

Experiment 74. To determine the water in soap, weigh 5 grams of shaved soap in a shallow aluminum dish, and heat it in the drying oven for several hours. By weighing again the percentage of loss, shows the water originally present.

SOAP POWDERS

Washing soda, $Na_2CO_3 10\ H_2O$, is often used, not only to soften hard water, but as a stronger washing agent than soap. This is a much better material than most of the so-called washing powders of the grocer. It should always be dissolved in a bottle or other vessel, and used as a solution in the quantities necessary. An excess disintegrates the fabrics, or "rots" the goods. Sometimes the washing powders or liquids on the market contain, in addition to the washing soda, a little soap or ammonium carbonate or a small per cent of borax, but they are much more expensive than the common washing soda, and no more efficient. Oxalic acid ($H_2O_2C_2O_2$), is often used in laundries, to whiten the goods by neutralizing the excess of alkali. This practice causes the rapid destruction of the fabric so treated.

Experiment 75. To test a washing powder for sodium carbonate, put a little of it in a test tube and add a few drops of hydrochloric acid. If there is a brisk effervescence, it will indicate the presence of a carbonate, and if the gas that is given off colors the flame of a Bunsen burner yellow, it indicates sodium.

BLUING

Bluing is the process resorted to in the laundry to overcome the slight yellow color of the clothes, and for the same purpose in the bleacheries where new goods are finished.

Indigo was one of the substances most commonly used some years ago. It was known to the ancient Egyptians as a dye and to the Romans as a pigment. The method of using it for bluing, as it is insoluble in water, is to tie up a lump in a cloth, and when soaked in water the finely

divided precipitate which is in suspension will give a blue color to the water, and to the clothes, which are immersed in it.

Prussian blue (ferric ferrocyanid), $Fe_4(Fe(CN)_6)_3$, is also used for bluing. It is insoluble in water and in mineral acids, but is decomposed by alkalies and dissolved by oxalic acid. It is generally used as a solution or "liquid blue," but this imparts to the goods a greenish blue color. On account of the ease with which it is decomposed by alkalies, there is danger that "iron rust" will be deposited on the goods if this form of blue is used.

Experiment 76. Make Prussian blue by the action of ferric chlorid, $FeCl_3$, upon potassium ferrocyanid, $K_4Fe(CN)_6$, in the presence of a few drops of hydrochloric acid. Treat this blue precipitate with an excess of sodium hydroxid, and heat to boiling. Notice the reddish brown precipitate of ferric hydrate, $Fe(OH)_3$.

Experiment 77. Make some Prussian blue, as in the previous experiment, and add to the precipitate, in the test tube, a few crystals of oxalic acid, and warm the mixture. Notice the intense blue solution obtained (liquid blue).

Ultramarine is an interesting artificial compound which is put upon the market in the shape of small "bluing balls." It is similar to the native mineral called "lapis lazuli," and is a double silicate of sodium and aluminum containing sulfur. Like indigo, it is insoluble in water and is simply held in suspension in that liquid. There is difficulty in preventing the formation of blue spots and streaks with the solid blue. This blue is extensively used for coloring wall paper and for "bluing" white sugar.

Experiment 78. To show the presence of sulfur in ultramarine, place a part of a bluing ball in water in a test tube,

and add to it enough hydrochloric acid to make the solution acid. Notice the odor of escaping gas when the solution is warmed, and test it for hydrogen sulfid, by holding in the gas a paper dipped in lead acetate solution. The paper turns black on account of the formation of lead sulfid.

Aniline colors made from coal tar are the basis of most of the liquid blues on the market at the present time. The soluble blues from this source are very numerous, and they are probably as satisfactory as anything for the purpose.

BLEACHING

At the present time neither bleaching nor dyeing is often carried on in the household. Large establishments are fully equipped for this work so that there is usually no reason for attempting it on a small scale.

The object of bleaching is to convert the color-bearing compound into a colorless product. In textiles the color is either of vegetable or animal origin. These colors may be removed either by a process of oxidation or by a process of reduction, and the agents used naturally divide themselves into these two classes.

Some of the oxidizing agents used are Calcium hypochlorite, Sodium hypochlorite, and Hydrogen peroxid. The bleaching of linen or cotton when it is spread on the grass and frequently sprinkled, is an application of the slow oxidizing property of the air. Chlorin is the active bleaching agent of the hypochlorites. These are used for linen and cotton goods, but not for silk or woolen fabrics. Hydrogen peroxid (H_2O_2) in acting as an oxidizing agent gives up half of its oxygen, with the formation of water. The common commercial hydrogen peroxid is a 3% solution in water, and is quite unstable. It is

useful as a milder bleach than the others mentioned and is used especially in bleaching hair, feathers, and ivory.

The chief reducing substance used in bleaching is sulfur dioxid (SO_2). It is generally used as a gas, and is formed whenever sulfur is burned in the air. The goods, as straw hats, woolens, or silks, are moistened and suspended in the vapor of SO_2. A dilute solution of sodium bisulfite, acidified with hydrochloric acid, may also be used for soaking the goods.

CHAPTER X

DISINFECTANTS, ANTISEPTICS, AND DEODORANTS

Since the health of the body depends so largely upon sanitary surroundings, it is important to consider what assistance modern science can offer to bring about the most hygienic conditions in the household. Infection, in general terms, is something capable of producing disease that comes to the body from without, and this infection usually reaches the system by the aid of certain lower forms of life known as microörganisms. These microorganisms may be distributed by impure water, by house flies, by flying dust, or by personal contact between individuals. We may try to check the progress of a disease within the body, where it is often a difficult problem. It is better to attempt to prevent the disease from invading the body by keeping the dangerous microbes out, or destroying them before they have an opportunity to enter. Those substances which are capable of checking the growth of the microörganisms, but without necessarily killing them, are known as "antiseptics"; so all "disinfectants," or destroyers of infection, are also antiseptics, but antiseptics are not necessarily disinfectants. The surgeon of to-day deals with wounds in such a way as to have the conditions aseptic, — that is, to have all germs excluded in the operation, — which is far better than attempting to destroy them when once introduced into the wound.[1]

[1] Sedgwick, "Principles of Sanitary Science and the Public Health," pp. 326, 327.

Those substances that destroy foul odors are often called disinfectants. This may be true or it may not. Some things destroy foul odors, or, in fact, simply cover them up without in the least going to the source of the trouble, and they are not disinfectants but simply "odor killers." The American Public Health Association's committee defines a disinfectant as, "An agent capable of destroying the infective power of infectious material." This does not, however, represent the popular view of the subject. Deodorants, though they may be of great value in their place, are not disinfectants or antiseptics.

Many people are in the habit of relying on the sense of smell to prove the presence of injurious as well as disagreeable substances in the air. The nose is, no doubt, an excellent watchman to protect the body, but whether we destroy a foul odor or simply overcome it by a more pungent one is not for the sense of smell to distinguish, for germs that render the air poisonous are not necessarily destroyed when no vile odor can be perceived. Because a substance is put on the market as a "microbe killer" or a "perfect disinfectant," it is not a proof that it is of any value, any more than the fact that a patent medicine is advertised as a specific for all the ills of the flesh is a proof that it will have that effect.

TESTS FOR DISINFECTION

These tests may be of three kinds:[1] —

First. From the practical experience of those engaged in sanitary work. Such diseases as smallpox, diphtheria, and scarlet fever have in many instances been contracted after months, from the use of clothing that has been about a patient, or from the occupancy of rooms where he has

[1] Dr. Sternberg, American Public Health Association.

been sick. Books that have been in the sick room have communicated disease months after they were removed from the room. If, after an attack of the disease, the rooms have been thoroughly disinfected, the disease has been completely stamped out in that place.

Second. Inoculation experiments have been made upon animals with infected material, and with the same material that had previously been subjected to the action of disinfectants. In the former case the disease was transmitted, and in the latter it was not, and thus the efficiency of the disinfectant was shown. It is known that in many infectious diseases the infecting agent is a germ, and in these cases the effect of disinfection is to destroy the germ. Experiments have been tried upon man with disinfected vaccine virus, and with the same virus that has not been thus treated, and the vaccination with the first was not successful, while that with the latter was. In this way the efficiency of a disinfectant was shown.

Third. Culture experiments, as they are called, are made directly on the disease germs. Here the germs are allowed to propagate in such fluids as extract of beef, or bouillon, and thus it is possible to study the life-history of these germs outside the body, and to learn what agents are efficient in destroying them.

Some bacteria multiply by " division " and others by " spores " also, and the latter are more difficult to destroy, because the organism is at that time in what may be called a resting stage. Often it is possible to prevent the growth and development of germs by the use of antiseptics or disinfectants; the germs are not destroyed, but the disease is arrested.

" An ideal disinfectant is one which, while capable of

destroying the germs of disease, does not injure the bodies and material upon which the germs may be found; it must also be penetrating, harmless in handling, inexpensive, and reliable.[1] This ideal disinfectant has not yet been discovered." There are, however, some inexpensive and common substances which can be used to destroy the germs of disease with good effect. Among the substances used as disinfectant and antiseptic agents, the following may be noted: —

Sunlight is an excellent disinfectant, if the material can be exposed to the direct rays of the sun. It has been shown that the bacillus of tuberculosis is killed by direct sunlight, and that of typhoid fever also under certain conditions. Even diffused light is of value as an adjunct to other methods for the destruction of germs, so there is reason in the common practice of "airing" bedrooms, and letting in all the sunlight possible.

Dry air is an excellent purifier, especially if accompanied by sunlight, chiefly on account of the large number of oxidizing bacteria which are present. It will remove moisture and often prevent decomposition in this way, for moisture is usually the friend of disease and decay.

Dry earth also allows oxidation and arrests foul odors. This fact is utilized in the dry earth closet.

Charcoal, especially that made from bones, is an excellent deodorizer and will remove foul odors quite readily. A handful of boneblack sprinkled on a piece of putrefying flesh will, after a short time, prevent any foul odors from escaping. Wood charcoal acts less effectively in the same way, but on account of its porosity absorbs gases very quickly.

[1] Price, "Handbook of Sanitation," p. 223.

Experiment 79. Into a bottle containing 200 cc. of *dilute* hydrogen sulfid water, which has the characteristic odor, put about 30 grams of boneblack and shake for some time. Filter, and, if the conditions have been carefully observed, the filtrate will have no odor of hydrogen sulfid gas, as it will have been absorbed by the animal charcoal.

Quicklime is also used for purposes of disinfection. On account of its cheapness, "milk of lime," $Ca(OH)_2$, is recommended, especially in camp sanitation, for destroying foul organic matter. Some physicians regard it as efficient as chlorid of lime.

A variety of substances are used to cover up vile odors, while they do not pretend to destroy them. The bad smells in the house may be overcome by burning sugar, cotton cloth, or coffee. The lack of personal cleanliness may be made less noticeable by the free use of perfumes, but this is a method belonging to an earlier kind of civilization rather than to our own.

More effective than any of the methods above noticed are the following — in the absence of spores: —

Heat, at a temperature of 302° F. (150° C.), may be used for disinfecting, and should be continued for at least two hours. A higher temperature, continued for a shorter time, will also destroy the bacteria. Sometimes clothing that would be injured by moist heat may be treated in this way. The goods may be heated in an oven, but should not be folded or piled close together. This method has been used for disinfecting by boards of health in large cities, but it is inferior to steam at the same temperature, and does not penetrate as well.

Sulfur dioxid, made by the burning of sulfur, is one of the oldest agents used for disinfection. A convenient way in which to use this is to put several pounds of sulfur

in an iron kettle, and to place that on bricks in a pan of water. Then light the sulfur by means of burning coals, or alcohol, and close the room very tightly. Five pounds is considered a sufficient quantity for a room containing 1000 cu. ft. of space. Sometimes a solution of sulfur dioxid is simply exposed to the air of the room. Ten pounds of the liquid would be necessary for 1000 cu. ft. of space. Liquid sulfur dioxid, inclosed in strong steel cylinders, may be purchased, and is extremely convenient, as it is only necessary to slightly open the valve to allow the gas to escape. The presence of moisture in the room or on the goods greatly assists the operation. The more tightly the room is closed, by pasting strips of paper over the cracks beside the doors and windows, the better the disinfection will be accomplished, and this precaution should not be neglected. Clothing and bedding should be opened out as much as possible, so as to bring it in contact with the sulfur dioxid gas, and the room should remain closed at least twenty-four hours. This gas is liable to bleach certain colors, so it should not be used with colored fabrics. Sulfur dioxid is, after all, only a surface disinfectant, and is said to be effective only against a limited number of pathogenic bacteria.

Carbolic acid, Phenol, C_6H_5OH, is an agent that has often been overrated, on account of its penetrating odor, and because a small quantity will overcome most other odors. This acid of a strength of 1 to 15,000 will prevent decomposition, but 1 to 1000 will be needed to destroy spores.[1] "While effective, in weak and in saturated aqueous solutions against many of the pathogenic bacteria, carbolic acid is not suited to the purpose of general disinfection."[2]

[1] Price, "Handbook of Sanitation," p. 252.

[2] Harrington, "Practical Hygiene."

It is an excellent substance to use for washing floors, walls, etc., and for disinfecting soiled clothing and discharges, as its antiseptic power is great. Although not very soluble in water, the solubility can be increased by the addition of glycerin.

The **cresols**, which are found in commercial carbolic acid, and are powerful germicides, are constituents of many of the disinfecting solutions now on the market, and they are believed by some to be superior to pure carbolic acid.

Copper sulfate, $CuSO_4 5\,H_2O$, or "blue vitriol," of about 10 % strength, is to be recommended, on account of its comparative cheapness, especially as a deodorant. It forms a blue solution, with water, and is very soluble in that agent.

Iron sulfate, $FeSO_4 7\,H_2O$, or the "copperas" of commerce, is very efficient for certain purposes. In the proportion of 2 lb. to a gallon of water, it may be used with great convenience and success to purify sink drains and cesspools. It may also be sprinkled in places where there are foul odors from the decay of organic matter, and they will be completely overcome.

Zinc chlorid, $ZnCl_2$, is very largely used as a disinfectant and a deodorant. As its solution, as well as that of zinc sulfate, is colorless, it will not stain the most delicate fabrics, so it can be used on any clothing that is not injured by washing. A 5 % or 10 % solution may be used for this purpose or for destroying foul odors.

Potassium permanganate, $KMnO_4$, since it is a strong oxidizing agent, may be used as a germicide in some cases, but is rather expensive. The use of this material in the purification of cistern waters has already been suggested (p. 84).

Hydrogen peroxid, H_2O_2, is now a commercial article, and its aqueous solution is sold at a reasonable price. There are some cases where this mild disinfectant may be applied with success, as it will destroy the bacillus of typhoid fever, cholera, and diphtheria quite readily.

There are, however, more efficient agents in disinfection than those that have been mentioned, because under the proper conditions they are of sufficient power to destroy the *spores of disease.*

Fire, it is well known, is effective to wipe out the disease germs. Old clothing and bedding should be burned rather than to try to disinfect it. The great fire of London, that followed the plague, was no doubt a blessing, in that it actually destroyed the last traces of the disease. That was more important in those days than it would be now, for they did not know the first principles of the science of disinfection.

Steam heat is one of the most valuable physical agents for the destruction of germs, as it kills bacteria at once, and spores after a short time. It is especially valuable for the disinfection of clothing, textile fabrics, carpets, etc., as it is very penetrating. Municipal authorities are making use of this method of disinfection on a large scale with great success. If it seems desirable, the material can be subjected to quite a high temperature by the use of superheated steam. In some communities machines mounted on wheels are used. A large apparatus has been introduced which is so constructed that the mattresses, bedding, etc., may be put into a chamber, from which the air is exhausted by means of a steam jet. Dry steam is then allowed to enter, and a temperature of 230° to 240° F. is maintained for 15 min., after which the steam exhauster again produces a practical vacuum,

and finally air is drawn through the chamber, and the dried materials may be removed. An apparatus of this character is used at the New York Quarantine Station.

Boiling water is one of the most satisfactory materials to use for disinfecting purposes. There are very few germs that can withstand a boiling temperature for half an hour. A temperature of 70° C. will be sufficient to kill the germs of cholera, tuberculosis, diphtheria, etc. Hot water is specially applicable to textile fabrics.

Calcium hypochlorite, $CaCl_2O$, chlorid of lime, or "bleaching powder," is a convenient disinfectant to use in some cases. The chlorid of lime holds the chlorin in combination very feebly, so that the smell of chlorin is always apparent in a good sample. The fresh sample should contain from 30 to 36 % of available chlorin, but if it is exposed to the air for a time it loses all its chlorin, so it must be kept in a sealed package until used. Calcium hypochlorite, the efficient substance in the bleaching powder, is soluble in water, but the solution loses its strength if not closely corked. It is decomposed when brought in contact with organic matter, and very effectually kills the germs of disease. Experiments with chlorid of lime as a disinfectant were begun as early as 1881, by Koch. They have been continued by Sternberg, Jaeger, Nissen, Klein, Duggan, and others, and all showed the very efficient character of this substance as a true germicide. Chlorid of lime is convenient to sprinkle about in the vicinity of bad odors, but the odor of the chlorin gas given off is disagreeable and in considerable quantities poisonous, and furthermore it has a very destructive action on metals, so it must be used with discretion.

Formaldehyde gas, HCHO, or "formalin," which is a 40 % solution of the gas, is one of the recent disinfectants

of great merit. It first came into general use in 1892. As it is a good germicide, has no injurious effect on fabrics and colors, and can be readily applied, it is taking the place of sulfur dioxid gas.

There are several ways of applying the gas: The evaporation of the solution of formaldehyde by means of heat, which may be applied in an ordinary kettle, is a simple method of disinfection, and one that has proved highly effective. Still another method of generating the gas is by pouring formaldehyde over crystals of potassium permanganate. An ordinary milk pail, set in a wooden bucket, so as to retain the heat generated by the powerful chemical action, is all the apparatus needed. In a sealed room, $3\frac{1}{2}$ ounces of permanganate, over which a pint of formaldehyde solution is poured, will be enough to thoroughly disinfect 1000 cubic feet of space. Since the evolution of gas is *very* rapid, the operator must leave the room immediately.[1] A polymerized formaldehyde, known as "paraform," is sold in pastilles, which when heated over a lamp give off formaldehyde gas; 2 oz. of paraform for 1000 cu. ft. of space, with an exposure of 12 hr., is recommended. A large number of lamps have been devised for vaporizing the liquid formalin or the paraform. The objects to be disinfected may be sprinkled with formalin, and inclosed in a tight box, so that they may be subjected to the vapor for several hours. Another method is to wet sheets with the solution and hang them in the room, which is tightly closed. Still another method, which may be used on a large scale, is to vaporize the formaldehyde gas in a retort outside the room, and force it through an opening into the tightly closed space.

[1] Rohe and Robin, "A Text Book of Hygiene," pp. 455, 456.

Mercuric chlorid, $HgCl_2$, or "corrosive sublimate," which stands probably at the head of all substances used as disinfectants and antiseptics, is a deadly poison. In solutions of 1 : 15,000 it stops decomposition, and a 1 : 2000 solution will kill most bacteria in two hours. If of 1 : 500 strength, it will act very quickly on bacteria and spores. It was said by Koch to exercise a restraining influence on the development of the spores of anthrax bacillus, even when present in the proportion of 1 : 300,000, but recent experiments show that its germicidal power was overrated. It is of importance to note, however, that mercuric chlorid is not very efficient where there is much albuminous material, because it so readily forms with the latter an insoluble substance.

If a wound is produced by a rusty nail or by any blunt instrument, so that the flesh is lacerated, it should be opened as well as possible, and cleansed with warm water and then filled completely with a solution of corrosive sublimate (1 to 1000), or a solution of carbolic acid of 5% strength should be injected to destroy any dangerous bacteria that may be present.

Dr. Sternberg recommends the following as a convenient solution of corrosive sublimate for general use: —

Mercury bichlorid	1 oz.
Copper sulfate	1 lb.
Water	1 gal.

The advantage of this solution is that we not only mix with the chlorid of mercury a valuable disinfectant, but the solution is colored blue, and so it is less liable to be used accidentally. It should be marked "Poison."

A disinfectant may be standardized and its relative antiseptic power determined by comparing its germ-

destroying power with that of a solution of carbolic acid of known strength and antiseptic value. Many of the so-called microbe killers on the market are shown to be almost worthless when measured by a standard of this kind.

CHAPTER XI

POISONS AND THEIR ANTIDOTES

SINCE many of the substances just discussed are poisons, and there are many others which are liable to be taken into the system by accident or otherwise, it is of importance to have enough knowledge in regard to them so that emergency treatment may be applied, but a physician should be immediately called.

GENERAL INSTRUCTIONS FOR TREATMENT[1]

There are some general directions that should be followed in any case of suspected poisoning. If the patient vomits, this action should be promoted by giving him copious draughts of warm water; if he is inclined to sleep, keep him awake; if he is faint, he should lie down and take stimulants; and if the extremities are cold, heat should be applied. After the stomach is emptied, give bland drinks such as starch, oatmeal, gruel, etc., with warm water. If an emetic is to be given, use a tablespoonful of ground mustard or of common salt in a tumblerful of lukewarm water. Other substances that may be used as an emetic are 30 grains of zinc sulfate, 30 grains of powdered ipecac, or 5 to 10 grains of copper sulfate.

The opportunities for accidentally taking a poison are

[1] *Pharmaceutical Era*, N.Y.

greatly increased with the use of insecticides about the house or farm and the common use of disinfectants. A common cause of poisoning is due to the careless habit of taking medicine out of an *unlabeled bottle*, a very dangerous procedure, or taking medicine from a bottle *in the dark*. Many of the drugs about the house, while perfectly harmless for external use, are liable to produce fatal results if taken internally.

A poison is a substance which, taken into the system and entering the circulation, may produce serious symptoms, or even death.

Poisons may be taken in small quantities repeatedly, as, for instance, with the food, and this is liable to produce *chronic poisoning*. They may also be taken in larger quantities so as to produce severe and dangerous symptoms, and we call this *acute poisoning*. It is common to distinguish between first those substances which, by their corrosive action, destroy the lining membranes of the alimentary canal, and second the true poisons, which affect the system after they have been absorbed and have entered the circulation.

To the corrosive class belong the alkalies, potash, soda, and ammonia, and the mineral acids, sulfuric, hydrochloric, and nitric. The symptoms of these poisons are an alkaline or acid taste in the mouth, followed by severe pain in the stomach.

The treatment, which must be as expeditious as possible, in the case of an alkali is to neutralize it immediately by administering some vegetable acid, as vinegar, or lemon juice in large quantities, and to protect the interior lining of the stomach by giving sweet oil.

In the case where acids have been taken, these must quickly be neutralized, best by milk of lime, limewater,

or calcined magnesia. It is not considered very safe to administer an emetic in severe cases or to use a stomach pump, lest the stomach be ruptured.

METALLIC POISONS

The salts of a few of the metals are extremely poisonous, and as salts of some of these metals are used in medicine, in the arts, as in paints and pigments, as well as for insecticides, there is considerable opportunity for them to become mixed with the food.

These metals are copper, zinc, lead, and mercury, and compounds of arsenic and antimony. The *symptoms* are severe pain in the stomach, usually with violent vomiting, and later pain in the bowels. When the presence of any of these is suspected, an emetic of a tablespoonful of ground mustard in water should be given immediately to empty the stomach.

The salts of *copper* are blue or green and have a strong astringent taste. There is no good antidote for the salts of copper. We must depend on getting it out of the stomach as quickly as possible by an emetic, unless, indeed, as is often the case with copper sulfate, it acts itself as an emetic.

The salts of *zinc* are white and astringent and might readily be mistaken for some harmless substance like magnesium sulfate or "salts." There seems to be no satisfactory antidote for zinc. It fortunately happens, however, that salts of zinc when taken into the stomach usually produce violent vomiting. This can be aided by taking warm water and ground mustard. The whites of half a dozen eggs mixed with water may also be given.

Salts of *lead* are white unless they are compounds of some other metal like chromium; the lead chromate,

which has been used for coloring candy, is of a brilliant orange color. Since lead salts are precipitated by sulfates, an excellent antidote for lead poisoning is magnesium or sodium sulfate. This should be followed by an emetic.

Mercury salts are also white. The most common of these are mercurous chloride (Hg_2Cl_2), commonly known as " calomel," which is not considered a poison, and corrosive sublimate ($HgCl_2$), which is extremely poisonous. Since the latter is a common disinfectant, there is every opportunity to take it by mistake. Corrosive sublimate forms an insoluble precipitate with albumen, so the method of treatment is to administer the whites of several raw eggs. If these are not at hand, a flour paste, on account of the gluten which it contains, may be used. An emetic should then be given, or in some cases the stomach pump may be used.

The substance known as *arsenic* is arsenic oxid (As_2O_3). It is a white, tasteless powder. Arsenic is often used as the basis of rat poisons and of vermin powders and fly killers. It is also the active ingredient of such insecticides as Paris green and London purple. " Rough on Rats " contains arsenic diluted with the white mineral substance barium sulfate and colored with lampblack. Arsenic is, therefore, a common poison. The symptoms of arsenical poisoning are severe pains in the stomach and bowels, and usually violent vomiting, accompanied by great thirst. The method of treatment is to give an emetic and afterwards freshly precipitated ferric hydrate ($Fe_2(OH)_6$) in tablespoonful doses. This may be prepared by the precipitation of ferric chlorid by ammonium hydrate, or by magnesium oxid.

Antimony salts are also poisonous. The most common

of these is tartar emetic, which is sometimes taken by mistaking the label tartar emetic for cream of tartar. The symptoms of poisoning are similar to those of arsenic poisoning. Unfortunately there is no good antidote for antimony and we must depend on removing it from the stomach by means of an emetic.

One of the common poisons is *oxalic acid.* This is a white crystalline solid, having the appearance of magnesium sulfate, for which it has often been mistaken. This acid and its salts are much used in the arts, as in laundry work and in dyeing and calico printing. The symptoms of poisoning are an *acid taste* in the mouth, pain in the throat and stomach, and persistent vomiting. If no antidote is given, it may be fatal in less than twenty-four hours. The antidote is lime in some form, as calcium carbonate, whiting, or precipitated chalk. An emetic may be given.

A very quick acting poison is *hydrocyanic* or *Prussic acid.* The common compound of this found on the market is potassium cyanid (KCN). This substance, as well as the acid, has an odor resembling that of peach pits, or bitter almonds. It finds abundant use in the arts, as in the separation of gold and silver from their ores, and in silver plating. The acid itself is a very volatile liquid, a few drops of which will produce almost instant death. The symptoms appear usually within five minutes after the poison is taken. The patient suffers from great weakness, vertigo, and a feeling of impending suffocation, as the muscles of respiration are particularly affected. With a large dose the patient almost immediately loses consciousness. The best method of treatment is to induce respiration as in a case of drowning. Aromatic spirits of ammonia may be used to stimulate breathing. The

stomach may be washed out with a dilute solution of potassium permanganate or hydrogen peroxid. There is usually very little time in which to treat the patient.

Phosphorus poisoning is not as frequently met with at present as when phosphorus was more extensively used in matches. In most of the " safety matches " the phosphorus paste is on the box and not on the matches. As phosphorus is an ingredient of common rat poisons and vermin killers, it might be taken accidentally.

The symptoms of acute phosphorus poisoning, which do not appear until several hours after the poison is taken, are pain in the stomach, severe headache, followed by nausea and vomiting. Sometimes the odor of phosphorus is noticed in the breath.

The best method of treatment is to give an emetic and wash out the stomach with a dilute solution of potassium permanganate. The antidote generally recommended, after the poison has been removed, is a dose of from fifteen to thirty grains of old oil of turpentine.

Another class of poisons quite distinct from those already mentioned is the *alkaloids*. These are the active principles of various plants and, although very numerous, only a few of the more common ones need be considered here.

Morphine is one of the alkaloids obtained from the juice of the seed capsule of the poppy. This dried juice is known as opium. Like all alkaloids its salts have a bitter taste, and very small quantities produce a marked effect on the system. Morphine is a constituent of laudanum, paregoric, and a very large number of sedatives, including the soothing sirups used for infants.

The symptoms, which usually appear within half an hour after the poison is taken, are first, a period of excite-

ment, which is soon followed by an intense desire to sleep. In the third stage the patient lies motionless, and an examination of the eyes will show that the pupils are contracted to the size of pinheads, and are insensible to the action of light.

In a case of morphine poisoning the physician will try to remove any poison that remains in the stomach by washing it out with a solution of potassium permanganate (5 grains in a teacup of water) with a stomach tube or syphon. Unfortunately it frequently happens that an emetic will not work. The next thing is to keep the patient moving, if it is at all possible, by walking him in the open air. Strong coffee may be administered in certain stages of the treatment.

Strychnin is a very active poison found in the *Nux vomica* bean. This poison is so often used to poison rats, moles, squirrels, dogs, and other animals that it is quite readily obtained.

The symptoms, which appear within a few minutes after the poison is taken, are an *intensely* bitter taste, followed very soon by twitching of the muscles and later by what are known as tetanic convulsions. During these spasms the muscles are rigidly contracted, and if relief is not afforded the spasms occur more and more frequently. An attempt to drink or a slight jar is liable to produce a spasm.

Unabsorbed poison should be removed from the stomach best by the hypodermic administration of apomorphin, or mustard in warm water may be given. A decoction of tannin with sodium bicarbonate is sometimes used to wash out the stomach. Chloroform may be cautiously administered by inhalation, or chloral hydrate by the mouth.

The plant popularly called monkshood or wolfsbane contains an extremely poisonous alkaloid known as *aconite*. The root looks something like horseradish and has sometimes been mistaken for it. Very small quantities of the tincture of the root or of the active principle will cause death. The symptoms, which appear within a few minutes after the poison is taken, are a peculiar tingling sensation in the mouth, followed by nausea, and frequently a strangling sensation. An emetic should be immediately given; artificial respiration should be maintained; stimulants should be administered.

Chloroform, if taken into the stomach, or when accidentally inhaled, acts as a poison. It should be removed from the stomach without delay, and artificial respiration should be given, accompanied by the inhalation of pure oxygen. If *chloral hydrate* is taken in excess above a medicinal dose, the patient should be treated as in a case of chloroform poisoning.

Poisoning by *carbolic acid* is very common, as it is readily obtained. It acts as a corrosive on the mouth and alimentary tract, and produces a burning sensation, and sometimes vomiting. In severe cases the patient is liable to become unconscious after a short time. The stomach should be washed out, and saccharated lime and alkaline sulfates or magnesia mixed with olive oil should be administered. The best antidote is whisky or brandy.

Wood alcohol, wood spirit or methyl alcohol (CH_3HO), is liable to be taken accidentally for grain alcohol (C_2H_5OH). It produces very serious and often fatal effects. In case the patient survives, he is liable to be permanently blind. Wood alcohol should be removed from the stomach by an emetic as quickly as possible.

An effort should be made to aid in the elimination of the alcohol by free sweating and by the administration of large quantities of water in which sodium bicarbonate (baking soda) is dissolved.

Ptomaine poisoning is often reported after eating food consisting of meat, chicken, fish, sausage, ice cream, or cheese. The usual symptoms are nausea and very severe pain in the stomach and bowels. Ptomaines are liable to be produced by the partial spoiling of foods, as when they are stored in damp, dark, dirty places, or in filthy containers. Contrary to common opinion, fruits and vegetables do not contain ptomaines. An emetic should be given and a physician called immediately.

There are numerous poisonous gases, but the one of special importance that should be here noted is *carbon monoxid* (CO). This is the most poisonous constituent of coal gas and water gas, and is also produced by the imperfect combustion of coal. As the carbon monoxid gas when pure has no odor, it is quite liable to be breathed accidentally.

The symptoms are a severe headache, vertigo, and muscular weakness, followed by general insensibility. The patient should be removed to the open air and treated by artificial respiration. The body should be kept warm, and ammonia may be cautiously inhaled.

It is important to remember that no gases except air can be breathed in safety. Other gases replace the oxygen of the air and the patient dies from suffocation or lack of oxygen. This refers to carbon dioxid and such vapors as that of gasoline, benzol, carbon tetrachlorid, and similar organic substances.

PART II

CHEMISTRY OF FOOD

CHAPTER XII

USE OF FOODS

In the consideration of so broad a subject as food, there is difficulty at the outset in giving it a satisfactory definition. The growth and repair of the body, as well as the potential energy by virtue of which the body is able to do actual work, need to be taken into account. Food has been defined as, "Anything which, when taken into the body, is capable either of repairing its waste or of furnishing it with material from which to produce heat or nervous and muscular work." [1] It is important to distinguish between food and medicine, and to notice that the latter may revive some vital action but will not supply the material which sustains that action. There are, however, many articles of diet, such as tea and coffee, and the food accessories, such as spices and condiments, which, although they do not strictly come within the above definition, are often useful to stimulate the appetite or to make the food more agreeable.

It is by no means essential that a single food should contain all the nutrients needed by the body, and in fact it is

[1] Hutchison, "Food and Dietetics," p. 1.

desirable that there should be a variety of food to stimulate the appetite and vary the character of the work which the organs of digestion are called upon to perform. Food may contain substances which must be broken up or decomposed by the body before it is of value, or it may contain substances which can immediately be taken into the circulation and utilized.

Some food is of use because it furnishes nearly all the nutritious substances needed by the body, while other foods furnish some special material in an economical or agreeable form. Some act readily in sustaining the body, or are easily digested; others are economical and offer a maximum amount of nourishment at a minimum cost.

Not only does food sustain the body, but there is a provision of nature that animals should derive great pleasure and satisfaction from eating, and this pleasure is due to both the sense of smell and that of taste; it is difficult to consider the function of one without that of the other.

Since these senses have not been cultivated as highly as the others, there is much room for further development; but there are some trades, such as that of the tea taster, the wine sampler, and the perfumer, where they are cultivated and utilized. The student of physiology finds it difficult to classify the sense of taste and smell, but it is possible to test the relative delicacy of these senses for various substances in different individuals. Some experiments [1] made by the author for the delicacy of the sense of taste, with a number of persons of both sexes, showed that it was possible to detect —

[1] *Science*, Vol. XI, p. 145.

	By Males (1 part in)	By Females (1 part in)
1 Bitter substance (quinine)	392,000	456,000
2 Acid substance (sulfuric acid) . . .	2,080	3,280
3 Salt substance (sodium chlorid) . .	2,240	1,980
4 Sweet substance (cane sugar) . .	199	204
5 Alkali substance (baking soda) . .	98	126

This showed that the sense of taste for bitter substances was far more delicate than for other classes, and that, except in the case of salt, the females could detect smaller quantities than the males. A separate set of tests made upon the pupils in a large Indian school[1] showed the same order of delicacy.

The knowledge that man has obtained as to which foods are wholesome and which are poisonous is largely the result of experience, and this experience was transmitted and grew from one generation to the next. Much is due, then, to our ancestors, who have had the courage to explore in the realm of untasted food. Even now, fatal mistakes in the selection of food are sometimes made, and children must in every generation be warned against brilliantly colored berries.

In the early ages the variety of food was not as great as now, for the people not only had *less skill in preparing* and *less experience in selecting* food, but they were obliged to depend on the chase, or to use only that food which was obtained in the immediate vicinity of their dwellings. They were not able to draw on all climates as we do, nor could they preserve the fruits of one season to consume in another. Grain was stored, fruits were dried, and meats

[1] *Kans. Univ. Quarterly*, Vol. II, p. 95.

were salted or dried, but beyond this little was done to preserve food.

A mixed diet, then, may be considered as evidence of advancing civilization. The palate becomes surfeited with too much of one kind of food, and so a change is welcome to stimulate the appetite. A monotonous diet is often a matter of necessity, but as soon as man has the opportunity to indulge in a mixed diet he is not slow to take advantage of it. With increased civilization the diet becomes more mixed in character, and on this account it does not interfere with the health to move from one locality or climate to another.

There is no doubt that man, as well as the lower animals, is benefited by a variety in food. It has been stated that "digestion experiments made with one kind of food material do not give on the whole as valuable results as those in which two or more food materials are used. In other words, it appears that with a mixed diet the same person will digest a larger proportion of nutriment than with a diet composed of a single food material." It is, of course, admitted that a mixed diet may present greater temptations to overindulgence in food.

It stands to reason that as some foods are too rich in proteins and others contain too large a proportion of carbohydrates, we should mix these in the proper quantities. This we do when we eat "bread and cheese," potatoes and beef, or rice, eggs, and milk in puddings.

As the system adapts itself to a certain kind of food and the stomach secretes gastric juice sufficient in kind and quantity for that food, it is not advisable after being accustomed to one kind of diet for a long time to change too suddenly to one that is entirely different, for indigestion may result.

The food selected should be suited to the habits, age, and employment of a person. A sedentary man will not thrive on a diet that is too stimulating, nor one engaged in active manual labor upon starchy foods alone. The food that is readily digested by an adult will not be at all adapted to the use of a young child.

There seems to be an instinctive selection of particular classes of foods for special climates — the Eskimo eats large quantities of whale blubber or fats; the Congo natives live mostly upon the plantain; the Polynesians subsist almost wholly on breadfruit. Even in the temperate zone we find that less meat is eaten in warm weather.

COOKING FOODS

Food, in order to be agreeable and wholesome, is usually cooked. This is necessary, —

First, to improve its appearance and to make it more agreeable to the eye and thus more appetizing.

Second, because warm food is often more agreeable than cold.

Third, to improve the flavor and develop the odor, particularly in the case of meats.

Fourth, in order to destroy any parasites or micro-organisms that may be contained in the food.

Fifth, to bring about certain chemical changes in the food, and thus better adapt it to digestion.

Sixth, to soften the material so that it may more readily be acted upon by the digestive fluids.

When proteins, such as those of meat, are acted upon by heat, even if the temperature is not above 170° F., they are coagulated and made more solid, but they are not so tough, and the bundles of fibers may more easily be

torn apart. When starchy food, as grains or potatoes, is cooked, the granules swell up, the outer cellulose envelope bursts, and thus after mastication the digestive ferments have an opportunity to come more intimately in contact with the starch. According to Sykes, moist heat, even below 185° F., causes most starch grains to burst, so that the starch is said to be gelatinized.[1]

CHARACTER OF FOODS

Food must be of such a character that it will build up the tissue of the body and supply it with energy for doing work. Incidentally the heat of the body is kept up by cell action, or, as one author puts it, "is a by-product" of functional activity. It is not necessary nor advisable, however, that all the food taken into the body should be positively nutritious. It will be a long time before the dreams of those who propose that we carry concentrated, or perhaps "synthetic," foods for several days' rations in the vest pocket will be realized. Not only would such food soon become positively insipid and disagreeable, but there is an absolute necessity for a certain amount of inert matter to distend the walls of the alimentary canal and distribute the nutrient material so that it may the more readily be absorbed.

FOOD MATERIAL NEEDED

Too large an amount of indigestible material in the food is, on the other hand, not satisfactory, for not only does it require of the different organs an undue amount of work

[1] Hutchison, "Food and Dietetics," p. 378.

in handling it, but the indigestible material may act as a positive irritant in the stomach and bowels. Too coarsely ground cereals sometimes overstimulate and irritate the mucous surfaces and thus become a source of impaired digestion. Not only should the food contain the nourishing material, but this should be of such a character that it is exactly adapted to the wants of the body.

In order to find out what the human body needs for its sustenance we may notice either the composition of the body, or we may study milk, which is the food provided by nature to nourish the young. The body contains the following chemical elements: oxygen, carbon, hydrogen, nitrogen, phosphorus, sulfur, chlorin, fluorin, silicon, calcium, potassium, sodium, magnesium, iron, manganese, and copper — sixteen in all.

The fact that these elements are found, however, means very little, if we have no information as to how they are combined, what proximate substances or compounds they form, for these elements might be combined to form innumerable substances.

According to a recent authority,[1] the body of a man weighing 154 pounds is made up of the following compounds, in approximately the quantities noted in the table: —

[1] A. H. Church, "Food," p. 5.

	Pounds	Ounces
Water, found in all the tissues	109	
Albumen, myosin, etc., found in muscular flesh, chyle, lymph, and blood	16	8.0
Calcium phosphate, found in tissues and liquids, but chiefly in the bones and teeth	8	12.0
Fat, distributed through the body . . .	4	8.0
Ossein, or collagen, found in the bones and connective tissues	4	7.8
Creatin, etc., in the skin, nails, and hair . .	4	2.0
Cartilagin, found in the cartilages . . .	1	8.0
Hæmoglobin, a substance containing iron, found in the blood	1	8.0
Calcium carbonate, in the bones	1	0.8
Neurin with lecithin, cerebrin, and similar compounds, found in the brain, nerves, etc.	0	13.0
Calcium fluorid, found in the bones and teeth	0	7.4
Magnesium phosphate, chiefly in bones and teeth	0	7.0
Sodium chlorid, throughout the body . .	0	7.0
Cholesterin, inosite, and glycogen, which are found in brain, muscle, and liver . . .	0	3.0
Sodium sulfate, phosphate, carbonate, etc., found in all liquids and tissues	0	2.2
Potassium sulfate, phosphate, and chlorid, found in all liquids and tissues	0	1.7
Silica, found in hair, skin, and bone . . .	0	0.1

Besides the above there are other complex compounds which occur in small quantities, but which are none the less of importance. Each of the *proximate principles* is made up of two, three, four, or possibly more, elements, and the compounds thus formed are some of them very complex in their structure.

CLASSIFICATION OF FOODS

No classification of food is very satisfactory, for although we may adopt the classification of Liebig and divide

the foods into the *carbonaceous*, or those which furnish heat, and *nitrogenous*, or those whose function it is to build up the body and furnish muscular energy, we are met at the outset by the fact that a large number of foods partially fulfill both functions. The *cells* of the body may draw their supply of energy from proteins, albuminoids, carbohydrates, or fats; but material for the manufacture and repair of tissues must come from the proteins. Heat is produced as a result of cell action.[1]

PROXIMATE SUBSTANCES

The proximate substances that go to make up foods include (1) **water**, (2) **fat**, (3) **carbohydrates**, (4) **protein and related nitrogenous bodies**, (5) **organic** acids, and (6) **the mineral salts**. Water, although absolutely essential as a constituent of the food material, need not be considered in the light of a nutrient. The fats which occur both in vegetable and animal foods are glycerids of the fatty and other acids. They contain only carbon, oxygen, and hydrogen. The oxygen is not present in sufficient quantity so that with the hydrogen it would form water. Fats are more fully discussed under Soap, p. 130, also on p. 57 and in Chapter XX.

[1] Hutchison, "Food and Dietetics," p. 3.

CHAPTER XIII

CELLULOSE, STARCH, DEXTRIN, ETC.

CARBOHYDRATE FOODS

THE carbohydrates include, with a few exceptions, only those compounds of carbon, hydrogen, and oxygen in which the hydrogen and oxygen are in the proportion to form water; that is, two parts of hydrogen to one of oxygen. Here are included the cereals and most standard foods, with the exception of the fats and those that are nitrogenous in character. These foods may be divided into: —

1. The cellulose group $(C_6H_{10}O_5)_n$, including cellulose, starch, inulin, dextrins, gum, etc.

2. The cane-sugar group $(C_{12}H_{22}O_{11})$, including cane sugar, milk sugar, maltose, etc.

3. The glucose group $(C_6H_{12}O_6)$, including dextrose, levulose, grape sugar, starch sugar, and galactose.

In addition to the above, inosite, $C_6H_{12}O_6,H_2O$, which occurs in muscular tissues, and pectose, the jelly-producing substance of fruits and vegetables, should according to some authors be classified as carbohydrates.

The ordinary analysis of a foodstuff includes a determination of the amount of *water*, *fat*, *nitrogenous matter*, *carbohydrates*, and *ash*. A study of thses analyses is of value in the comparison of different foods.

CELLULOSE

Cellulose $(C_6H_{10}O_5)_n$ is the main product of vegetable life, and forms the principal part of wood, cotton, paper, etc. In fact, cotton fiber, linen rags, and "washed" filter paper are nearly pure cellulose. It is insoluble in most chemical reagents, but may be dissolved in cuprammonia, and from the solution the cellulose may be precipitated as a gelatinous mass which is similar to aluminum hydroxid in appearance and dries to a hard mass.

When cotton or paper is treated with a mixture of nitric and sulfuric acids, a substance called nitrocellulose is formed. One variety of this substance is guncotton. When the nitrocellulose is dissolved in ether, it yields collodion. Another product known as celluloid is made by dissolving certain varieties of nitrocellulose in ether and camphor, and afterwards evaporating off the solvent. There are some special properties of cellulose, which are illustrated in the experiments which follow this section.

Although some of the lower animals, as the rodents, can digest cellulose and make it available for nutrition, the stomach of man has this power only to a limited extent. According to Atwater, some of the cellulose of the food is absorbed, but much of it passes through the system unchanged and is of value only as it helps distend the alimentary canal. Whatever digestion takes place in the intestines is due to the action of certain microörganisms, by which fatty acids are produced, which upon absorption yield nutriment. Herbivorous animals eat food that contains large amounts of cellulose associated with smaller quantities of starch, fat, and nitrogenous substances.

Experiment 80. To 3 volumes of water add 1 volume concentrated sulfuric acid and cool the mixture. Pour this into an evaporating dish, and immerse in it strips of unsized paper, and allow them to soak for 10 to 15 seconds. Wash thoroughly, first with water, then with dilute ammonia solution, and again with water. Dry the parchment paper or amyloid thus obtained, and notice its peculiar properties. Although it has undergone a physical change, it still has the composition of paper. Unsized cloth may be treated in the same way.

Experiment 81. Another sample of unsized paper is treated with strong sulfuric acid, and allowed to stand for 5 minutes. It dissolves into a pulpy mass, which is then washed *thoroughly*, and tested with tincture of iodin. If a purple color is produced, it is an indication that the cellulose has been changed to dextrin.

Experiment 82. To show the action of alkalies on cellulose, treat a piece of cotton cloth for 20 minutes with a solution of sodium hydroxid of a specific gravity of 1.25. Wash and dry, and notice the change in the structure of the fiber. This is practically the process used to make "mercerized" goods. In this process the linear contraction is about 25%, and the increase of strength is 50%. See also p. 115.

***Experiment 83.** Make cuprammonia (Schweitzer's reagent), $Cu(NH_3)_4SO_4$, as follows: Add to a cold solution of copper sulfate, a cold solution of sodium hydroxid, filter, wash, and dissolve in concentrated ammonium hydroxid and add a little dilute sulfuric acid. Schweitzer's reagent should be freshly prepared, and should be capable of immediately dissolving cotton or fine grades of filter paper. It may be used to dissolve cellulose from pectose, in working with the microscope.

***Experiment 84.** Dissolve cotton or filter paper in Schweitzer's reagent, and add to the solution an excess of hydrochloric acid. This will precipitate the cellulose, which may be washed on a filter so that its properties can be examined. See also p. 115.

STARCH $(C_6H_{10}O_5)_n$

The starches are regarded as the most important of the foods of this group; indeed, they form the principal part of most vegetable foods. Starch is stored up in seeds, roots, fruits, and vegetables, and is adapted for food purposes; and is utilized by man and the lower animals. As the bee stores honey for future use, so the plants store starch for the use of the germinating seed, and man takes advantage of both kingdoms of nature. The carbohydrates circulate through the plant in the form of sugar, but they are stored up in the form of starch, and this store can be drawn upon by the plant in time of need.

Sources of Starch. — The most important source of starch is the cereals. The amount of starch contained in some grains is as follows: —

	Per Cent		Per Cent
Wheat flour	75.6	Rice	79.4
Graham flour	71.8	Buckwheat flour	77.6
Corn meal	71.0	Barley	62.0
Oatmeal	68.1	Sorghum seed	64.6
Rye flour	78.7	Millet	60.0

Various roots, tubers, and stems are also sources of starch, as follows: [1] —

	Per Cent		Per Cent
Potato	18.0	Artichokes (gum and inulin)	10.2
Yam	15.3	Sweet cassava (tapioca)	30.98
Sweet potato	15.0	Arrowroot (*Maranta arundinaceæ*)	22.93
Carrots (pectose)	2.5	Onions (pectose, etc.)	4.8
Parsnips	3.5	Radishes (carbohydrates)	4.6
Turnips (pectose)	3.0		
Beets (pectose)	2.4		

[1] For complete composition, see "Foods," by A. H. Church.

Some less familiar sources of starch are the Sago palm, and the roots of the Bitter cassava (tapioca), Salep (orchids), Tous les mois (*Canna edulis*), and Celeriac.

The leguminous plants also furnish starch, thus: —

	Per Cent		Per Cent
Beans	57.4	Peanuts	117
Peas	51.0	Soy beans	12.5
Lentils	56.1		

There is some starch in all fruits, but those mentioned are of special value on account of the amount which they contain: —

	Per Cent		Per Cent
Bananas	22.0	Breadfruit	14.0
Plantain	15 to 20		

Some nuts contain considerable starch, thus: —

	Per Cent		Per Cent
Acorns	43.35	Horse chestnuts	68.25
Chestnuts	42.10		

Of the above, the most important *commercial* sources of starch are wheat, corn, rice, potatoes, acorns, and chestnuts. Special varieties of starch are also put on the market under the names of tapioca, arrowroot, and sago. The other starch-bearing vegetable products, as well as those specially noted, are used in some countries as food.

WHEAT

The examination of the wheat grains by the microscope shows that upon the outside there are bran cells; next to these are cells of a thin cuticle; within these are the gluten cells, and finally, nearer the center of the grain, are the

starch cells. If a longitudinal section be made of a wheat grain, and it is examined by a microscope of low power, it will be found to be made up of the "germ," which is near one end, the "kernel," and the "bran," or outer envelope.[1]

Wheat is a typical bread-making cereal. Its proteins differ from those of other cereals, and are composed chiefly of a globulin, an albumin, a proteose, and the two bodies, gliadin and glutenin.[2] The two latter form the gluten, and give the characteristic properties to wheat flour. The products of wheat are used as human food in many forms. There are nearly a hundred different grades of food materials made from wheat by the patent-roller process of milling.[3]

Wheat sown in the fall is called soft or winter wheat, and that sown in the spring is hard or spring wheat. The kernels of winter wheat are usually larger than the spring variety. Spring wheat usually contains more gluten than winter wheat.

In comparing the milling and the food value of wheat, it should be remembered that this depends largely on the amount of nitrogenous matter present. A high percentage of proteins is not always a sure indication of the milling value of the wheat. It is the gluten content of the flour on which the bread-making qualities chiefly depend. The percentage of dry gluten is considered the safest index to use in the comparison of different samples of flour.

A comparison of the analysis of different samples of wheat is of interest:[4] —

[1] For full description, see Jago, "The Science and Art of Bread Making," p. 265.

[2] Osborn and Voorhees, *Am. Chem. Jour.*, Vol. XV, p. 392.

[3] Bul. 13, Pt. 9, U. S. Dept. Agric., Div. Chem.

[4] Wiley, Bul. 45, U. S. Dept. Agric., Div. Chem.

	Moisture	Albumi-noids	Ether Ext.	Crude Fiber	Ash	Carbo-hydrates
Domestic . . .	10.62	12.23	1.77	2.36	1.82	71.18
Foreign	11.47	12.08	1.78	2.28	1.73	70.66
World's Fair, 1893	10.85	12.20	1.74	2.35	1.81	71.09
Mean, given by Jenkins & Winton						
Spring . . .	10.40	12.50	2.20	1.80	1.90	71.20
Winter . . .	10.50	11.80	2.10	1.80	1.80	72.00
Mean, by König						
Miscellaneous .	13.37	12.51	1.70	2.56	1.79	68.01
Spring Wheat .	13.80	14.95	1.56	—	2.19	67.93
Russian, Spring	12.56	17.65	1.58	—	1.66	65.74

There are, however, some special varieties of wheat, including a Russian wheat, that contain more protein. Twenty-four analyses of this variety show an average of 21.56 % of nitrogenous substances.[1] Durum wheat is one of the hard, glassy varieties especially adapted to the making of macaroni. The ash of wheat contains about 30 % of potash, 3 % of lime, 12 % of magnesia, and 47 % of phosphoric anhydrid, besides the other constituents that are usually found in the ash of plants. From this it is easy to understand that a large amount of mineral matter is taken from the soil by a crop of wheat.

WHEAT FLOUR

Wanklyn states that wheat flour has the following composition : —

	Per Cent		Per Cent
Water	16.5	Starch, etc.	69.6
Fat	1.2	Ash	0.7
Gluten, etc.	12.0		

[1] Blyth, "Foods, Their Composition and Analysis," p. 146.

As wheat flour was formerly made, it was crushed between millstones, forming a rather coarse product; this was bolted, and gave fine flour, middlings, and bran.

At the present time, by the roller process, in which the grain is crushed and sifted repeatedly, a large number of grades of flour may be produced.

The highest grade of flour produced is known as Patent flour, while the lower grades are often known as Family, Bakers', and Red Dog flour. The following analyses show the percentage of the different products produced from the grain, and the grades obtained by different millers: —

	Minnesota [1]	Arkansas [2]
Patent flour	57.82	17.65
Straight flour	—	50.35
Bakers' flour	11.28	—
Low-grade flour	6.77	2.32
Bran	17.64	24.10
Shorts	3.79	1.10
Screenings, waste, etc.	2.70	4.48
	100.00	100.00

The commercial value of a flour depends on its color, texture, and the quantity of gluten which it contains. The character of this gluten also differs under different conditions of climate and soil. Bakers prefer a flour with a high percentage of tenacious gluten, which permits the production of a loaf of bread containing a maximum amount of water. This water may be as high as 40%.[3] In large bakeries the best results are obtained by mixing different grades of flour.

[1] Snyder, Minn. Agric. Exp. Sta., Bul. 90.
[2] Teller, Ark. Agric. Exp. Sta., Buls. 42, 53.
[3] U. S. Dept. Agric., Div. Chem., Bul. 13, Pt. 9.

ANALYSIS OF DIFFERENT KINDS OF FLOUR

Some of the constituents of different kinds of flour are as follows: [1] —

	Moisture	Nitrogen N × 6.25 Proteins	Dry Gluten	Ether Extract	Nitrogen-free Extract
Patent wheat flour	12.77	10.55	9.99	1.02	74.76
Common market wheat flour	12.28	10.18	9.21	1.30	75.63
Bakers' and family flour	11.69	12.28	13.07	1.30	73.87
Indian-corn flour	12.57	7.13	—	1.33	78.36
Rye flour	11.41	13.56	—	1.97	73.37
Barley flour	10.92	7.50	—	.89	80.50
Buckwheat flour	11.89	8.75	—	1.58	75.41

For a comparison of the different grades of wheat flour, the following table, which gives the results of work done at the University of Minnesota,[2] is of interest: —

Milling Product	Water	Protein N × 5.7	Fat	Carbo-hydrates	Ash	Phosphoric Acid
First patent flour	10.55	11.08	1.15	76.85	0.37	0.15 per ct.
Second pat. flour	10.49	11.14	1.20	76.75	.42	.17
Straight or Standard patent	10.54	11.99	1.61	75.36	.50	.20
First clear-grade flour	10.13	13.74	2.20	73.13	.80	.34
Second clear-grade flour	10.08	15.03	3.77	69.37	1.75	.56
"Red Dog" flour	9.17	18.98	7.00	61.37	3.48	—
Shorts	8.73	14.87	6.37	65.47	4.56	—
Bran	9.99	14.02	4.39	65.54	6.06	2.20
Entire-wheat flour	10.81	12.26	2.24	73.67	1.02	.54
Graham flour	8.61	12.65	2.44	74.58	1.72	.71
Wheat ground in laboratory	8.50	12.65	2.36	74.69	1.80	.75
Gluten flour	8.57	16.36	3.15	70.63	1.29	—

[1] Bul. 13, Pt. 9, U. S. Dept. Agric., Bu. Chem.

[2] Snyder, U. S. Dept. Agric., O. Exp. Sta., Bul. 101.

From the figures in the table it will be seen that there is a gradual decrease in the water content from the first patent to the "red dog" grade of flour, and there is a noticeable increase in the ash from the higher to the lower grades. The determination of ash has been taken advantage of to determine the grade of a particular sample of flour.

There is but little difference in chemical composition between the first and second grades of patent flour. The "standard" patent flour contains about 12 per cent of protein, while the wheat from which it was made contains 12.65 %. The second clear and "red dog" samples are characterized by a high per cent of protein, fat, and ash. Judging by their proximate composition only, these latter flours might appear to have a higher nutritive value than the higher grades; but, when judged by the character of the bread made from them, they must be assigned a much lower value (see p. 175).

The wheat product of the United States for 1915 was over 1,011,505,000 bu.

CORN (*ZEA MAYS*)

Corn, though coming originally from America, has been largely cultivated in some other countries. It grows well in temperate and warm climates all over the world. The grains keep well, and may be parched, or ground into meal. There are a large number of varieties of corn, a special variety being adapted to each special climate. By careful selection C. G. Hopkins[1] has increased the protein of a variety of corn from 10.92 % to 14.26 %.

Some of the preparations of corn are hominy, samp,

[1] Rep. Ills. Agric. Exp. Sta. Bull. 100 (1905).

corn meal, cracked corn, cerealin, and a large number of corn starches. The examination of the analyses made by the Department of Agriculture[1] shows that corn has the following composition: —

	Per Cent		Per Cent
Moisture	10.04	Crude fiber	2.09
Albuminoids	10.39	Ash	1.55
Ether extract (mostly fats)	5.20	Carbohydrates	70.69

CORN AS FOOD

Corn is especially rich in fats, although deficient in nitrogenous matters and mineral salts. It is a very fattening food, both for man and the lower animals, and is well adapted to serve as food for those who do hard manual labor. As it was first introduced into Europe as food for lower animals, it has been somewhat difficult to overcome the prejudice of the people against it, although the United States government has sent a commission to Europe to demonstrate to the people the value of corn as a food for man. Corn meal is quite digestible, though slightly laxative. Cornstarch is frequently used as a substitute for other starches in food for invalids. In this country, both yellow corn meal, made from hard corn of the Northern States, and white corn meal, made from the white corn of the West, are in use.

Referring to the relative nutritive properties of wheat and maize, Wiley[2] says: "There is a widespread opinion that the products of Indian corn are less digestible and less nutritious than those from wheat. This opinion, it appears, has no justification, either from the chemical

[1] Bul. 45, Dept. Agric., Div. Chem., p. 25.

[2] U. S. Dept. Agric., Div. Chem., Bul. 13, Pt. 9, p. 1290.

composition of the two bodies, or from recorded digestive or nutritive experiments. In round numbers, corn contains twice as much fat or oil as wheat, three times as much as rye, twice as much as barley, and two thirds as much as hulled oats. Indian corn has nearly the same content of nitrogenous matter as the other cereals, with the exception of oats."

The largest corn crop of the United States, that of 1912, amounted to 3,124,746,000 bu.; that of 1915 was 3,055,000,000.

OATS

Oats are grown in northern regions throughout the civilized world. The composition of oatmeal is as follows: [1] —

	Per Cent		Per Cent
Water	12.92	Dextrin and Gum	2.04
Nitrogenous matter	11.73	Starch	51.17
Fats	6.04	Fiber	10.83
Sugar	2.22	Ash	3.05

Oatmeal contains considerable fat, protein, and mineral salts. The nitrogenous substance is composed of "gliadin" and plant casein. The gliadin has a much higher percentage of sulfur than the gliadin of wheat. Von Bibra states that oatmeal contains from 1.24 to 1.52 % of albumen. It has proved an excellent foodstuff, though, on account of the quality of the gluten, it is not adapted to use for making bread. Within the last forty years it has come into extensive use in the United States as a breakfast food. It is stated that the so-called Scotch groats are prepared by removing the outer husks

[1] Blyth, "Foods, Their Composition and Analysis," p. 170.

and leaving the grain almost whole, and then this is ground between millstones. True Scotch groats are heated over perforated iron plates and slightly parched before being ground. In most cases where oatmeal can be digested, it forms a very valuable food, but it requires long cooking (from one to two hours) and considerable skill in preparation to make it wholesome. On this account, although it has been used so extensively for many years, recently other foods have to some extent been substituted for it. Possibly we have not appreciated the fact that it is a very hearty food and especially suitable for those who live an outdoor life. The oat crop of the United States for 1915 was 1,540,000,000 bushels.

RYE

This cereal grows best in northern countries, where it is sown in the fall and protected by the covering of snow in the winter. It is the favorite food of northern Europe, where it is made into "black bread." It was formerly quite extensively used as food in the extreme northern part of the United States. The grain is also much used for malting purposes. It makes a better bread when mixed with wheat flour in the proportion of two of wheat to one of rye. This grain is more liable than other cereals to be affected by the fungus known as ergot. Grain that is modified in this way is unwholesome and may be poisonous. On account of its composition, rye dough is very sticky, and of a dark color. The composition of American rye is as follows: —

Moisture	Albuminoids	Ether Extract	Crude Fiber	Ash	Carbohydrates
8.6	11.32	1.94	1.46	2.09	74.52

The rye crop of the United States for 1915 was 49,200,000 bushels.

BARLEY

This grain was originally a native of western Asia, and is well adapted to high northern latitudes. Both barley meal and "pearl barley," that is, the grain deprived of the outer coating by attrition, are used as food. By far the largest part of the barley that is grown is used for making malt (see Chapter XXV). Barley flour does not yield a light bread, but may be mixed with wheat flour for this purpose. The following is the composition of the grain: —

Moisture	Albuminoids	Ether Extract	Crude Fiber	Ash	Carbohydrates
11.31	10.61	2.09	4.07	2.44	69.47

237,000,000 bushels of barley were produced in the United States in 1915.

MILLET

This cereal is raised for stock food in the United States, but is a staple diet for man in central Africa, southern Europe, and eastern Asia. In protein value it is between wheat and rice. Although the bread made from millet is nutritious, it soon crumbles and becomes dark in color.

RICE

This cereal is a native of India and is grown in the East, in southern Europe, and in the southern United States, where it was introduced in 1644. For its successful cultivation an abundance of water, so that the fields can be irrigated, and a high temperature are required. Although rice is deficient in albuminoids, fat, and mineral matter,

it is estimated that it is the main food of a third of the human race.[1] To prepare the grain for the market it is separated from the hulls, and is usually polished by passing between leather rollers which remove the outer layer. This process of "polishing," however, removes much valuable nutrient material. The grains are also ground into flour or may be used for making starch. Rice has the following composition, according to König:[2] —

	Moisture	Albuminoids	Ether Extract	Crude Fiber	Ash	Carbohydrates
Hulled . .	12.58	6.73	1.88	1.53	.82	76.46
Polished .	12.52	7.52	.84	.48	.64	78.00

This grain is exceedingly digestible when cooked, especially by steaming, so that the individual grains are softened and swollen. It cannot be made into raised bread unless mixed with wheat or rye flour, as it is deficient in gluten.

It is evident from the composition of rice that it is not fit to use as an exclusive food, but should be eaten with butter, eggs, and milk, as in puddings, or with meat, fish, peas, or beans, to supply the necessary food ingredients. When rice is cooked in a soup or with meat, the mineral salts, which at best are not very abundant, are fully utilized in the food.

PRODUCTION OF RICE

For the year 1913 there was produced in the United States 715,111,000 pounds of rice, and this was about

[1] "Foods, Their Origin, Composition and Manufacture," Tibbles.
[2] Bul. 45, U. S. Dept. Agric., Div. Chem., p. 34.

$\frac{1}{200}$ of the total production of the world.[1] We import annually not less than 200,000,000 pounds from foreign countries.

POTATOES

The potato, *Solanum tuberosum*, is closely allied botanically to several interesting plants, including the tomato, tobacco, henbane, and capsicum. Although a native of Chili and Peru, it was probably carried to Spain early in the sixteenth century, and introduced into Virginia from Florida by the Spanish explorers, and into Great Britain from Virginia in 1565 by Sir John Hawkins. The potato was recommended by the Royal Society of London in 1663 for introduction into Ireland as a safeguard against famine. It is a question whether its introduction there has not aggravated the famine tendency, since the peasants learned to depend almost entirely on potatoes, and this crop sometimes failed from disease. It was not cultivated in New England till the eighteenth century, when it was introduced from Ireland; and now this "much traveled" tuber is one of the most important articles of food.

Potatoes grow well and are a staple crop in the New England States, New York, Michigan, Canada, and throughout the Middle West. Even where the season from frost to frost is quite short a good crop may be raised. 359,000,000 bushels were grown in the United States in 1915,[2] and the world's crop is over 5,500,000,000 bushels.

The following analysis is given by Church: —

[1] "Rice, Cleaning and Polishing," Stuart, U. S. Dept. of Agric.

[2] Monthly Crop Report, Sept. 1916.

	Per Cent		Per Cent
Water	75.0	Dextrin and pectose	2.0
Albuminoids	1.2	Fat	.3
Extractives, as solanin and organic acids	1.5	Cellulose	1.0
Starch	18.0	Mineral matter	1.0

This shows that 93 % of the potato is water and starch, and that, as in the case of rice, the amount of fat, albuminoid, and mineral matter is very small. But with even this small mount of nitrogenous substance, experiments have proved that only 49 % of this is protein, the remainder being ammonium compounds and salts, which are of no value as nutrients. The grains of potato starch are very large as compared with those of the cereals. Commercial starch is readily obtained from this tuber, and this is a convenient method for utilizing small and immature potatoes. The starch is also very readily attacked by ferments, and so potatoes are often used as an ingredient of home-made yeast.

A cross section of the potato shows that it is made up of a rind, which constitutes $2\frac{1}{2}$ %; a fibrovascular layer, $8\frac{1}{2}$ %; and the flesh, 80%; and an analysis has shown that the fibrovascular layer is much richer in mineral matter and proteins than the body of the potato, so by the ordinary method of peeling much valuable nutrient material is lost. It is estimated that 20 % of the actual weight of the potato is usually thrown away as refuse. The mineral matter is rich in potash salts, and when the potato is peeled before boiling, much of this and of the valuable protein matter is dissolved and wasted. If potatoes are peeled, there is less loss of nutrient material if they are plunged immediately into boiling water and boiled rapidly. Potatoes may also be steamed or baked without appreciable loss.

Potatoes are evidently not suited for use as the *staple* article of diet, but are extremely useful as food when eaten with butter, milk, eggs, meat, and fish, and this is indeed the ordinary method of using them. They are very valuable to prevent scurvy, and usually form an indispensable addition to the diet upon shipboard, where salt meats are necessarily used. During the Great War in Europe potato flour, or dried and ground potato meal, were added to that made from cereals in making bread.

SWEET POTATOES

The sweet potato belongs to the *convolvulus* family, and is probably a native of tropical America, though it grows well in temperate climates. The yam is a different plant, although there is a resemblance between the tubers of this plant and the sweet potato. Sweet potatoes have the following composition: [1] —

	Per Cent		Per Cent
Water	75.0	Pectose	.9
Albuminoids, etc.	1.5	Fat	.4
Starch	15.0	Cellulose	1.8
Sugar	1.7	Mineral matter	1.5
Dextrin and gum	2.2		

CASSAVA (TAPIOCA)

Tapioca is a starch product made from the roots of several plants of the *manioc* family, that grow in parts of South America and in other tropical regions. One of these, the *Manihot utilissima*, or bitter cassava, yields a milky juice, which in the preparation of the tapioca is mixed with the starch, and this contains considerable of

[1] Church, "Food," p. 107.

the poison known as prussic acid, HCN. In the preparation of the tapioca, this juice is washed away from the grated root and the pulp is heated on hot plates, to drive off the last of the prussic acid; this treatment also ruptures most of the starch grains.[1] Tapioca is considered one of the most useful foods for invalids. A tapioca flour is made by grinding the dried pulp, and this forms the chief food of the natives in many tropical countries. A so-called "pearl tapioca" is often made from potato starch.

ARROWROOT

The commercial arrowroot is made from the rhizome of the *Maranta arundinacea*, a plant growing in the West Indies. The roots are washed, reduced to a pulp and mixed with water, strained, and from the milky water the starch settles out. The granules of the starch thus prepared are among the largest used in commerce. The product when cooked is one of the most valuable foods for the diet of invalids. In making and packing the so-called Bermuda arrowroot, great care is observed to keep it from contamination.

SAGO

This form of starch is made from the pith of the sago palm, which grows in Sumatra, Java, Borneo, and the West Indies. The starch is washed out of the pith after the tree has been felled, and is converted into "pearl" sago by granulation. A palm tree frequently yields 500 pounds of sago.

[1] Bul. 44, U. S. Dept. Agric., Div. Chem.

OTHER STARCHY FOODS

Chestnuts contain 15 % of sugar and from 25 to 40 % of starch. Although used for making bread by the French, Spanish, and Italians, it is not a very digestible form of starch.

Some of the other starches of interest are *salep*, which is made in Smyrna, from a species of orchid, and is used in Turkey and the East as food; *Tous les Mois*, manufactured in the West Indies from the tubers of *Canna edulis;* and a starch prepared in Japan from the bulbs of several varieties of lily.

All the more expensive starches are liable to adulteration with cheap starches, such as that of wheat, corn, or rice, and these adulterations can only be detected by the use of the microscope.

LEGUMES

Under the general name of "pulse" may be classified such important foods as peas, beans, soy beans, lentils, etc., which come from the leguminous plants. It is said that peas came originally from the country around the Black Sea. Beans were introduced into Europe from India, and lentils were grown from the earliest time in southern Europe and the country to the east and south of the Mediterranean Sea. The soy bean is an important article of food in China and Japan, and supplements very well the rice diet in these countries.

These foods are characterized by containing not only large quantities of starch, but proteins as well, so they may be considered as furnishing, at the same time, both kinds of nourishment needed by the body. On this account, the legumes are often classified with the nitrog-

enous foods. Plants of this family have a special provision for getting enough nitrogen for their growth, in the little nodules on the roots, which consist of masses inclosing bacteria, which have the power of fixing the free nitrogen of the air so it can be utilized by the growing plant. Peas and beans also contain some sulfur and phosphorus, in combination with the nitrogenous body known as legumin, or vegetable casein.

Legumin of the unripe peas appears to be more soluble and more readily digested than that from the dried seeds. On the whole, the leguminous foods are not readily digested in the stomach, but are quite thoroughly absorbed in the intestines.[1] If, however, the food is not ground to a state of very fine subdivision, there is quite a loss of proteins in the process of digestion.

The following analyses are given by Hutchison: —

	Water	Proteins	Carbohydrates	Fat	Cellulose	Mineral Matter
Green peas .	78.1	4.0	16.0	0.5	0.5	0.9
Dried peas .	13.0	21.0	55.4	1.8	6.0	2.6
Beans . . .	11.7	23.0	55.8	2.3	4.0	3.2
Lentils . .	11.7	23.2	58.4	2.0	2.0	2.7

While the leguminous foods are excellent diet, yet they should be supplemented by the food containing starch and fat, and so we use beans and rice, or, more commonly, baked beans and fat pork. In the latter case, the oil or melted fat permeates the mass in cooking, and flavors the beans, and, at the same time, furnishes a more digestible diet than if the same amount of fat was used for frying.

[1] Hutchison, "Food and Dietetics," p. 223.

Green peas and green beans, as well as "string beans," do not furnish a very highly nutritive diet, as they contain from 80 to 90 % of water, but, on account of the ready solubility of the proteins and their agreeable flavor, they form a valuable food product.

On account of the cheapness of this form of protein food, a pea sausage (*Erbswurst*) has been introduced as a part of the rations in the German army. It is a cooked food, made of pea meal mixed with fat pork and salt, so prepared that it will not readily spoil.[1] In cases where it is necessary to economize in the cost of food, this can be readily attained by the use of relatively large quantities of peas, beans, and lentils, for they contain large amounts of nutrients at a comparatively low cost.

***Experiment 85.** To prepare legumin, treat pea flour with successive quantities of cold water, made slightly alkaline. In this solution precipitate the legumin with acetic acid. To purify, dissolve the precipitate in weak potassium hydroxid solution and reprecipitate with acetic acid. The pure alkaline solution should give a violet color, with copper sulfate solution.[2]

BANANAS

The banana, although a variety of the plantain family, is smaller and more delicate in flavor than the common plantain. Although the banana grows as far north as Florida, yet the climate best adapted to its cultivation is that of Cuba, Jamaica, the Congo region in Africa, and especially Central America.

The tree grows to a height of from 12 to 40 feet. When the stalk of the tree is cut down, new stalks shoot up from the roots. The tree is propagated on a new plantation,

[1] Thompson, "Practical Dietetics," p. 163.

[2] Blyth, "Foods, Their Composition and Analysis," p. 181.

not by seeds, but by cutting off roots from old plants, and planting in rows, very much like the hills of corn. The banana comes to maturity from the root in from ten to twelve months. Each bunch that is produced will contain from 150 to 180 bananas.

The banana-growing industry has increased enormously in the past thirty years, and at the same time the cost of the fruit has decreased. Bananas which a few years ago cost 10 cents apiece can now be bought at from 10 to 15 cents a dozen. The fruit is shipped to the United States in fast steamers that are capable of carrying 40,000 bunches per trip. In 1914, 41,000,000 bunches were shipped into the United States, or an estimated consumption of forty bananas per capita per year.

Bananas are peculiar in combining the sweet qualities of a fruit with the nourishing qualities of a vegetable. On account of the presence of so much nutriment, and because bananas grow so luxuriantly, it is stated that a given area of ground will support a greater population if planted to bananas than if planted with wheat.

The analysis of bananas compared with some other starchy foods is as follows: —

	Ripe Bananas [1]	Potatoes [2]	Banana Flour from Ripe Fruit [3]	Wheat Flour [3]
Moisture . .	73.10	78.3	13.0	13.8
Nitrogenous substances .	1.87	2.2	4.0	7.9
Fat	.63	.1	.5	1.4
N.-free extract	23.05	18.4		
Carbohydrates			80.0	76.4
Cellulose . .	.29			
Ash	1.06	1.0	2.5	.5

[1] König, "Chem. d. M. Nah. u. Genuss.," p. 1120.
[2] Rep. Ct. Agric. Exp. Sta. [3] Hutchison, p. 249.

From this analysis it is evident that bananas are rich in sugar or starch and contain a fair quantity of proteins.

Some persons find bananas difficult of digestion, but this is no doubt due to the fact that they are often picked so green that they are irregularly ripened. The partially ripened fruit is composed chiefly of starch, and this should be cooked before it is eaten by invalids. As the fruit ripens, this starch changes to a mucilaginous substance, and then to dextrin and glucose.

A banana flour is made by carefully drying selected fruit, and is said to be easily digested and extremely nutritious. This is about the only fruit flour that can be readily made, and so it has been used with success as a part of the diet of patients suffering from gastric irritability and similar diseases. A plantain meal is made by drying the pulp of the unripe fruit.

GENERAL METHOD FOR MAKING STARCH

In the United States starch is made especially from corn (maize), wheat, and potatoes; in Europe, potatoes, corn, and rice are used; and in the West Indies starch is made from arrowroot or the sago palm.

Several processes are used for the manufacture of starch. In making cornstarch by the Durgen system a continuous stream of water at 140° F. is allowed to flow over the corn for three days in order to soften it. It is then ground in water and the milky liquid is run into nearly horizontal revolving sieves, or square shaking sieves. The starch passes through the bolting cloth, and the refuse, which consists of the cellular tissue, is retained. The refuse is afterwards pressed and used for cattle food. The water, holding the starch in suspension, is allowed to stand in wooden

vats until the starch settles out, when the water is finally drawn off. In order to purify the starch and remove the gluten, the crude starch is agitated with a solution of caustic soda, allowed to settle, and the clear liquid drawn off. Next the starch is washed and run into a deep vat, and the highest of a series of plugs is removed from the side to allow the starchy liquid to run out. A little later a lower plug is removed, and so on until the vat is nearly empty; then a fresh lot of starch water is run in. The products from the different lots of starchy water drawn off are of different grades and used for different purposes. After again sifting through bolting cloth, the starch solution is run into wooden settling boxes, and when sufficiently compact is cut into blocks and dried on an absorbent surface of plaster of Paris in a current of warm air. It is important that the temperature of the moist starch be not raised above 60° C.

In another process the milky liquid is run upon an inclined settling floor, and made to run slowly back and forth toward the lower end of the room. The starch is deposited and the clear water run off at the lower end. Sometimes alkali is not used, but the germ of the corn is mechanically removed before the starchy part of the corn is ground.

In making wheat starch the softened grain is sometimes ground and then allowed to ferment for 14 days in large tanks at 20° C., with frequent stirring. By the fermentation which takes place the gluten is attacked and the starch grains are set free. The impure liquid is drawn off and the starchy mixture is poured through revolving sieves or made to pass through the meshes of hempen sacks. The subsequent operations are like those above described.

By another process wheat flour is mixed with water, and the dough is washed repeatedly in bags under a jet

of water. Starch is obtained from the water by running it into settling tanks, and the gluten which remains in the bags may be utilized for making macaroni.

Experiment 86. Mix a handful of flour with water, and place the dough in a cloth bag, hold under a stream of running water, kneading constantly with the hands. The starch will be carried away with the water and the gluten will remain in the bag. Dry the contents of the bag, and examine its structure.

The insoluble proteins of wheat obtained by kneading a dough of wheat flour in a stream of water consist of about 75 % of true gluten (gliadin and glutenin), together with small percentages of non-gluten proteins, mineral matter, fat, starch, fiber, and other non-nitrogenous matter.[1]

Experiment 87. As the value of a flour for baking bread depends on the amount of gluten present, the following method has been used to compare the gluten-content of flours.[2] Place 10 g. of flour, wet with an equal weight of water, in a porcelain dish, and work into a ball with a spatula, taking care that none adheres to the dish. Allow the ball to stand for an hour, then knead it with the hand in a stream of cold water until the starch and soluble matter are removed. Allow the ball of gluten to remain in cold water for an hour, then roll into a compact ball with the hands, place in a watch glass, and weigh; this is moist gluten. Dry for 24 hours on a water bath and again weigh, and then record the weight as that of dry gluten.

SUBSTANCES RELATED TO STARCH

Dextrin ($C_6H_{10}O_5$) is a substance that suggests gum in its properties, and indeed it is put upon the market under the name of British gum. Several varieties of dextrin exist, and it is evident from a study of their composition that

[1] Norton, *J. Am. Ch. Soc.*, 1906.

[2] Wiley, "Agric. Analysis," 2d edition, Vol. III, p. 530.

they may result from the breaking down of the starch molecule, by means of dilute acids or ferments.

Commercial dextrin is made either by heating starch or flour to a temperature of 210–280° C., or by moistening the starch with a mixture of dilute nitric and hydrochloric acid, slowly drying the paste, and heating it to a temperature between 110° and 159° C.

Dextrin obtained by either of these processes is a white or yellowish powder. As it is mostly of the variety known as erythrodextrin, its aqueous solution gives a brown color with iodin. It is slightly soluble in dilute alcohol, but insoluble in 60 % alcohol. The brown crust on the outside of a loaf of bread is composed mostly of dextrin. Dextrin is used on the back of postage stamps to make them adhesive.

The *Gums* are colloidal bodies occurring in the juices of plants. They either dissolve or swell up when brought in contact with cold water. Some of the more important gums are: Gum Arabic and Gum Tragacanth. Their food value has only been imperfectly studied.

Inulin ($C_6H_{10}O_5$) is a starchlike substance found in chicory, potatoes, artichokes, elecampane, dahlias, and dandelion roots. It is a white powder, readily soluble in boiling water, and converted into levulose by boiling with water or acids.

PHYSICAL PROPERTIES OF STARCH

Starch is really made up of little grains, those of different plants being of different size and shape, and showing concentric markings. This indicates that the grains are built up of different layers; that is, a layer of true starch and then a layer of a kind of cellulose. These grains are not soluble in cold water, alcohol, or ether, so they are not

washed away when the plant is broken. If boiling water is poured upon the starch, or if starch is heated to from 70° to 80° C., the grains burst and the whole forms a gelatinous mass, having, when dry, the stiffening properties with which we are familiar. In order to thoroughly cook starch so that it will be digestible, it should be noted that at some time in the process it should be heated as high as 100° C. Boiled with water for a long time, the starch goes into solution, 1 part dissolving in 50 parts of water. In the process of cooking starchy foods, the grains are ruptured, and in this condition they are much more easily attacked by the digestive fluids.

As all starches are of practically the same composition, the only way of detecting the source of any specimen of starch is by the use of the microscope. Although there are so many varieties, yet the grains of each differ from the others in size or shape, or in their appearance with polarized light. The expert can thus detect adulterations and the substitution of a cheap starch for an expensive one. For illustrations of the different starches, see Leach [1] (plates).

Experiment 88. Place some starch in a test tube with a little water and shake moderately, then filter and test the filtrate for starch by adding tincture of iodin (see Experiment 93). If there is no blue color, how is this accounted for?

CHEMICAL PROPERTIES OF STARCH

When starch is heated to 100° C., it changes gradually to soluble starch. At a temperature of 160° to 200° C. it is changed to dextrin $(C_6H_{10}O_5)_n$; from 220° to 280° C. it is changed to pyrodextrin, which is soluble in alcohol. Of

[1] Leach, "Food Inspection and Analysis," 3d ed.

course, if heated still higher, it is decomposed and gives off combustible gases.

Experiment 89. Prepare starch from potatoes by peeling, scraping to a pulp, putting in a cloth bag with water, and squeezing out the milky juice. Allow this to settle (not over 24 hr.), pour off the clear liquid, and dry the residue at a temperature not above 70° C. on a water bath.

Experiment 90. Make starch from corn meal and from acorn meal, by grinding with water in a mortar and treating as in Experiment 89.

Experiment 91. Make an emulsion of green bananas, and prepare starch from this, as above.

Experiment 92. Make starch paste by mixing a few grams of one of the specimens of starch prepared above with cold water and pouring this into 100 times as much boiling water and heating for a short time.

Experiment 93. Test a small portion of this starch paste, after cooling, with a few drops of tincture of iodin. (This is made by dissolving iodin in alcohol.) A blue color indicates the presence of starch.

Experiment 94. To make dextrin $(C_6H_{10}O_5)_n$, heat about 20 g. of starch very cautiously in a porcelain evaporating dish, with constant stirring. The temperature should be between 210° and 280° C.

Experiment 95. Another method of making dextrin is to moisten about 10 g. of starch with a very little dilute nitric acid, dry the paste on a water bath, and finally heat slightly above 100° C.

Experiment 96. Dissolve some of the dextrin made above in cold water (characteristic test); add to this solution an excess of alcohol, to precipitate the dextrin.

Experiment 97. Prepare Fehling's solution as follows: —

(*a*) Dissolve 34.639 g. of copper sulfate in 500 cc. of water.

(*b*) 178 g. of Rochelle salts and 30 g. of sodium hydroxid are dissolved in water and diluted to 500 cc. Label the solutions *a* and *b*.

Experiment 98. *Fehling's Test for Dextrose.* To a dilute solution of commercial glucose, contained in a medium-sized test tube, add 5 cc. of *a* and 5 cc. of *b*, and boil for a few minutes. The formation of a yellowish red, or, in case of an excess of dextrose, of a red flocculent precipitate of cuprous oxid, Cu_2O, indicates dextrose.

Experiment 99. Test a portion of the dextrin made in previous experiments, dissolved in water,

(*a*) for starch with tincture of iodin,

(*b*) for sugar (dextrose) with the Fehling's solution, as mentioned above.

HYDROLYSIS OF STARCH

By boiling with dilute acids starch is converted into dextrin and maltose, and by prolonged boiling into dextrose. This process of taking up the molecule of water is known as hydrolysis. (See equation below.) Many ferments like the ptyalin of saliva and the pancreatic ferment change starch to sugar ($C_6H_{12}O_6$, dextrose).

Experiment 100. *Conversion of Starch to Dextrose.* Use about 3 g. of the starch made above; mix with 200 cc. of water and 20 cc. dilute HCl. Heat on a water bath in a flask for 2 hours, or boil for 15 minutes. Cool, neutralize with sodium hydroxid, and test a portion of the solution by Fehling's solution for dextrose.

If starch is digested with the diastase of malt, what is known as "hydrolysis" takes place and the starch is

changed to maltose, $C_{12}H_{22}O_{11} + H_2O$, which resembles dextrose. The action of malt upon starch is expressed by the equation: —

$$\underset{\text{Starch}}{3\,C_6H_{10}O_5} + H_2O = \underset{\text{Dextrin}}{C_6H_{10}O_5} + \underset{\text{Maltose}}{C_{12}H_{22}O_{11}}.$$

Experiment 101. Filter some saliva, and digest this with starch paste in a test tube, kept in a water bath at a temperature not above 98° F. (36.6° C.) for 15 min. Test half of the solution for starch and the other half for maltose by Fehling's solution.

Experiment 102. To show the presence of sulfocyanic acid (HCSN) in saliva, evaporate cautiously a few cc. in a small porcelain crucible and test with a few drops of dilute ferric chlorid ($FeCl_3$). The reddish coloration indicates the presence of sulfocyanids.

Experiment 103. Prepare malt extract by digesting coarsely pulverized malt for several hours with enough alcohol to cover it. Filter and set the solution aside in an evaporating dish. When the alcohol has evaporated, dissolve the residue, which contains the ferment known as diastase, in water. Make a thin starch paste, cool to about 62° C., add a little of the diastase, and digest for 15 min. at this temperature. Test a portion of the solution for starch. If it is still present, continue the digestion, but if it is all converted, test for maltose by Fehling's solution.

Strong nitric acid in the cold acts upon starch, producing several nitroamyloses, collectively known as xyloidin. These resemble nitrocellulose (see p. 171).

CHAPTER XIV

BREAD

Whether we consider the white bread of the American housewife, the black bread of the German peasant, the oatmeal "scones" of the Scotch laborer, or the corn "pone" of the Southern plantation, each is a valuable nutrient and a staple food in its locality.

Bread consists practically of flour, with the addition of a little salt and water, mixed into a paste and baked before a fire. The simplest flour is that made by the natives of many countries, by grinding, or "braying," the grain between two stones. This was one of the earliest mortars used. It is quite probable that the name "bread" comes from the word "brayed," referring to this method of breaking the grain.

There are two general methods of making light dough: —

1. **By non-fermentation methods.**
2. **By fermentation methods.**

1. NON-FERMENTED BREAD

There are a large number of methods used for making dough without the use of yeast. Unleavened bread is the simplest form of this food and is made without any aëration, by mixing the flour and water and baking. Examples of this kind of bread are the passover cake of the Israelites, the sea biscuit and hard tack used on shipboard and in the army, the Scotch oat cake, and the corn-meal

" pone " so extensively used in the South. Graham and whole-wheat flour are used in the same way, thus making a bread that is claimed to be more wholesome, and which may be kept for a much longer time than the ordinary raised bread. Unleavened bread is not, however, considered as appetizing as raised bread, but has the advantage that on account of its hardness and dryness it must be thoroughly masticated and mixed with the saliva, and thus becomes the more readily digested.

The object of these processes for making the dough light without the use of yeast is to shorten the time and labor of making the bread. The following methods may be noticed, and will serve to show that much thought has been devoted to the subject.

ENTRAPPING AIR

1. By mixing Graham flour or wheat flour with water, or milk, and beating it vigorously for some time, and baking quickly in cast-iron pans, a fairly light bread results. The raising-substance in this case is the air that is entrapped in the dough. Gems and muffins are made in this way in some dietary establishments.

2. A modification of the above plan is to mix the materials with snow, and then bake quickly in a hot oven. In this case the cook depends on the air that is entrapped in the snow crystals to raise the dough.

3. Eggs, beaten to a froth, will entangle sufficient air to make dough very light and spongy. This fact is taken advantage of in the making of sponge cake.

ADDITION OF A VOLATILE SUBSTANCE

4. Brandy, wine, or any liquor, diluted, may be used instead of the water, in the mixing of dough, and when this

is baked the expansion and volatilization of the alcohol will raise the dough. It is probable that very little of the alcohol will remain in the finished product, but there are some objections to this method, both on account of its expense, and because of the flavor imparted to the product by the liquor that remains.

5. Ammonium carbonate, $(NH_4)_2CO_3$, is an extremely volatile substance, and if a solution, or the fine powder, be mixed with the flour, it will, as it escapes in the process of baking, raise the dough. This has been used with yeast, by the baker, to obtain very light bread. The ammonia salt is also used to overcome any excess of acids due to the overfermentation.

ADDITION OF SUBSTANCES WHICH EVOLVE CARBON DIOXID

6. Sodium bicarbonate ($NaHCO_3$), when heated, gives off a part of its carbon dioxid gas and some water; and as this escapes it will render the dough light. There is, however, a great disadvantage in the use of this substance, as there remains in the bread sodium carbonate, an alkaline substance that renders the bread unwholesome.

7. A modification of this process, however, will give an excellent product. If the baking soda is used with molasses, which usually contains some free acid, then the alkali is neutralized, and carbon dioxid is set free, and the material is very light. This is taken advantage of in making gingerbread. If the molasses is not sufficiently acid, a little vinegar may be added to it.

8. Aërated bread, as made by Dr. Dauglish, an English physician, in 1856, was introduced a few years ago, and for a time seemed to be so popular in this country

that there was a prospect of its replacing the other varieties that were on the market, but it has not found favor here in recent years. It is used extensively abroad, especially in London. It possesses a characteristic taste that is entirely different from that of fermented bread. In the manufacture of this bread the flour is mixed in a strong iron vessel, provided with a mechanical stirrer, with salt, and water that is impregnated with carbon dioxid gas. The dough is forced out of the apparatus by the pressure of the gas, and is molded into loaves, that are immediately placed in the oven. The vesiculation is produced by the carbon dioxid gas, which, in its efforts to escape, raises the dough. There is no chemical change in the flour, as in fermentation methods of making bread, and so none of the flour is lost in the process.

9. A process that is somewhat allied to this, but one that has not been received with very much favor, is to mix the flour with baking soda, and then to add to the water that is to be used in the mixing of the bread sufficient hydrochloric acid to combine chemically with the soda; and in this way there would be left in the bread nothing but common salt, in accordance with the equation: —

$$NaHCO_3 + HCl = NaCl + H_2O + CO_2.$$

10. By the use of sodium bicarbonate and freshly curdled sour milk, excellent results may be attained. In this case, there is left in the bread sodium lactate, an entirely harmless salt, and carbon dioxid gas is set free. Some skill is of course required to get sufficient soda in the material to exactly combine with the acid of the milk. One teacup of sour milk will usually neutralize a teaspoonful of baking soda. If the milk is not acid enough for the purpose, it may be acidified still further by the addition of

some vinegar. Biscuit and cakes are not only raised by this process, but they are rendered richer by the fat and the casein of the milk. If too much soda is added, the product is, of course, yellow, alkaline, and unwholesome. The equation is: —

$$NaHCO_3 + C_2H_5OCOOH = C_2H_5OCOONa + H_2O + CO_2.$$

Lactic Acid — Sodium Lactate

11. Sodium bicarbonate and cream of tartar are often used to render dough light. The first of these may be mixed with the flour, and the latter with the water that is used in mixing the dough, or both may be sifted and mixed with the flour. This is an excellent method, as the only salt remaining in the bread is " Rochelle salt," a comparatively harmless substance, though in large quantities it acts as a laxative. The proportions of each substance to be used, as estimated from the molecular weight, are one part of sodium bicarbonate to two parts of cream of tartar. As the powders do not differ very much in bulk, they may be measured with a teaspoon. The equation representing the reaction that takes place is as follows: —

$$KHC_4H_4O_6 + NaHCO_3 = KNaC_4H_4O_6 + CO_2 + H_2O.$$

The tartrate is made from " argols," that are collected in the bottom of wine casks in the process of fermentation.

12. By the use of baking powders. These powders are of four kinds: —

1. Cream-of-tartar powders.
2. Phosphate powders.
3. Alum powders.
4. A mixture of alum and phosphate powders.

The use of baking powders is more common in the United States than abroad. It is said that the amount consumed in one year will amount to more than 50,000,000 pounds. The only thing added to the soda and cream of tartar or other substance furnishing the " acid " in the manufacture of a baking powder is some starch or flour, which is known as a " filler." This is said to be necessary to prevent the ingredients from combining too soon. In all the powders baking soda is used to afford the requisite amount of carbon dioxid gas, the only difference between them being in the acid salt or chemical used to set it free.

STRENGTH OF BAKING POWDERS

The value of a baking powder depends on the per cent of carbon dioxid gas that is set free when the powder is put into water.

The amount of available carbon dioxid obtained from a powder may depend not only on the quality of the constituents, the skill with which they are mixed, and their correct proportion, but also largely upon the *age* of the powder. The bicarbonate of soda and the acid potassium tartrate in the cream-of-tartar powders, or the bicarbonate of soda and the sodium sulfate, or the alum, in the so-called alum powder, will gradually combine, especially if they are not absolutely dry, as long as powder is kept in stock, and so the strength of the powder will be diminished. Of the thirty-one samples of baking powder examined by the author, six were cream-of-tartar powders, two phosphate powders, fifteen alum-phosphate and eight alum powders. The amount of available carbon dioxid varied from 1.41 % to 15.29 %.

Experiment 104. To show the evolution of carbon dioxid from a baking powder, place some of it in a 250 cc. flask, pro-

vided with a cork through which passes a delivery tube having its outer end below the surface of 100 cc. of limewater placed in a beaker. When water is added to the baking powder, the gas is rapidly evolved and produces a precipitate in the limewater: —

$$Ca(OH)_2 + CO_2 + = CaCO_3 + H_2O.$$

Experiment 105. Test a baking powder for flour or starch as mentioned in Experiment 93.

A powder of the cream-of-tartar class by a complete analysis would show the following constituents: [1] —

	Per Cent
Total carbon dioxid (CO_2)	12.25
Sodium oxid (Na_2O)	11.03
Potassium oxid (K_2O)	11.71
Calcium oxid (CaO)	.19
Tartaric acid ($C_4H_4O_6$)	35.14
Sulfuric acid (SO_3)	.12
Starch	18.43
Water of combination and association, by difference	11.13
	100.00

The available carbon dioxid was found to be 11.13 %. This powder would then be made from about 25 parts of sodium bicarbonate, 50 parts of cream of tartar, and 25 parts of starch. The small quantities of other substances are accidental impurities in the chemicals used. Sometimes a little ammonium carbonate is used with the above powder. As this is really a mixture of ammonium carbamate and carbonate, the reactions at first would be: —

$$NH_4CO_2NH_2 = 2\ NH_3 + CO_2.$$

Ammonium Carbamate Ammonium Carbonate

and $$(NH_4)_2CO_3 = 2\ NH_3 + H_2O + CO_2.$$

[1] Bul. 13, Pt. 5, U. S. Dept. Agric., Div. Chem.

Therefore the ammonia salt is entirely volatilized by the heat of the oven.

Experiment 106. To test a baking powder for ammonium carbonate, place about 15 g. in a beaker, and over this put a watch glass carrying on its under side a moistened slip of red litmus paper. If the beaker is warmed carefully on an iron plate or stove, the ammonia, if present, will, after some time, color the paper blue.

Experiment 107. To test for tartaric acid or a tartrate in a baking powder, place about 10 g. in a beaker, add water, and after a short time filter off the starch and insoluble material. To the filtrate add a little copper sulfate solution and some sodium carbonate, and boil the solution for a few minutes. Filter off any copper hydroxid that may be present and dilute the filtrate about four times. If the solution is a distinct blue, especially after adding more sodium carbonate and boiling again and filtering, this indicates the presence of tartrates.[1]

13. Phosphate powders are made from the acid phosphate of lime, — often called superphosphate, — sodium bicarbonate, and starch. The phosphate is made by the action of sulfuric acid on bones, consequently it sometimes contains a little calcium sulfate, but a small quantity is not considered an adulteration. The reaction that takes place is as follows: —

$$CaH_4(PO_4)_2 + 2\,NaHCO_3 = CaHPO_4 + Na_2HPO_4 + 2\,CO_2 + 2\,H_2O.$$

The substances that are left in the bread are considered about as harmless as the Rochelle salts, and are by some thought to be of actual value to the system. On analysis these powders are shown to have the following composition: [2] —

[1] Bailey and Cady's "Qualitative Analysis," 8th ed., p. 186.
[2] Bul. 13, Pt. 5, U. S. Dept. Agric., Div. Chem.

	Per Cent
Total carbon dioxid $(CO)_2$	13.47
Sodium oxid (Na_2O)	12.66
Potassium oxid (K_2O)	.31
Calcium oxid (CaO)	10.27
Phosphoric acid (P_2O_5)	21.83
Starch	26.41
Water of combination and association, by difference	15.05
	100.00

Available carbon dioxid 12.86 %. This powder would be made up of about the following ingredients: —

	Per Cent
Sodium bicarbonate	26
Acid calcium phosphate	37
Starch	27
Water of association, etc.	10

Experiment 108. To test for phosphoric acid, ignite about 5 g. of the powder in a porcelain dish, heat the residue with nitric acid, dilute, and filter. To the filtrate add ammonium molybdate, and warm (do not boil), when the formation of *an abundant* yellow precipitate of ammonium phosphomolybdate shows the presence of phosphoric acid. It should be remembered that the ash of flour will show a small quantity of this acid.

14. Alum powders are often mixed with phosphate powders, and Professor Mallet states that he finds that this is usually the case. The alum used is soda alum, if this is the cheapest, though sometimes "cream-of-tartar substitute" (calcined double sulfate of aluminum and sodium) is used. If alum is used, the equation would be: —

$$2\,NH_4Al(SO_4)_2 + 6\,NaHCO_3 = 2\,Al(OH)_3 + 3\,Na_2SO_4 + (NH_4)_2SO_4 + 6\,CO_2.$$

The analysis of a powder of this class shows the following constituents: [1] —

[1] *Loc. cit.*

	Per Cent
Total carbon dioxid (CO_2)	7.90
Sodium oxid (Na_2O)	6.99
Calcium oxid (CaO)	.12
Aluminum oxid (Al_2O_3)	3.65
Ammonia (NH_3)	1.02
Sulfuric acid (SO_3)	10.11
Starch	45.41
Water of combination and association, by difference	24.80
	100.00
Available carbon dioxid	6.41

This powder would, therefore, be made from about the following constituents: —

	Per Cent
Sodium bicarbonate	21
Ammonia alum (anhydrous)	15
Starch	45
Water of crystallization and association	19

In this particular powder the amount of available carbon dioxid is low, but this is probably because the powder had been in stock for some time. Alum powders will give as much available carbon dioxid as any others.

Many experiments have been made to decide exactly what is left in the bread when alum and phosphate powder is used. From these investigations it is shown that the powder which contains enough phosphate to combine with the alum is a better powder than the one consisting of alum alone. This is so because the phosphate is less liable to be soluble than the hydrate of aluminum. It was also proven that the interior of a loaf of bread seldom reaches the temperature of 100° C., and, on this account, the aluminum hydrate will not be dried sufficiently to render it insoluble. Professor Mallet says: "A part of the aluminum unites with the acid of the gastric juice and is taken up into solution, while at the same time the

remainder of the aluminum hydroxid, or phosphate, throws down, in insoluble form, the organic substance constituting the peptic ferment." [1] From experiments made upon himself, he concludes that aluminum hydroxid taken into the system tends to produce indigestion. See also more recent experiments made under the direction of the U. S. Dept. of Agriculture.

Experiment 109. To test for sulfuric acid, ignite about 10 g. of baking powder in a porcelain or platinum dish, cool, and boil in a beaker with strong hydrochloric acid until nearly all dissolved; dilute with water, filter, heat nearly to boiling, and add barium chlorid. The formation of a fairly abundant precipitate of $BaSO_4$ indicates sulfuric acid.

Experiment 110. If sulfuric acid has been found, alumina is probably also present. To test for this, apply the logwood test mentioned in Experiment 117.

Experiment 111. Another test for aluminum salts in baking powders, that may be applied even in the presence of phosphates, is to burn about 2 g. of the powder in a porcelain or platinum dish, extract the ash with boiling water, and filter. Add to the filtrate enough ammonium chlorid solution so that the mixture shall smell distinctly of ammonia. The appearance of a white, flocculent precipitate, especially on warming, indicates the presence of alumina. The equation is: —

$$Na_2Al_2O_4 + 2\ NH_4Cl + 4\ H_2O = 2\ Al(OH)_3 + 2\ NH_4OH + 2\ NaCl.$$

Calcium phosphate would be insoluble in the water, and alkaline phosphates would be precipitated only when alumina was present.[2]

Experiment 112. To test for alum in cream of tartar, add to the sample an equal quantity of sodium carbonate, burn the mixture, and treat the ash as in the preceding experiment.

[1] *Loc. cit.*

[2] Leach, 31st Ann. Rep., Mass. State Bd. Health, 1899, p. 638.

Experiment 113. As cream of tartar is often adulterated with calcium phosphate, to test for this impurity, ignite a sample of the cream of tartar and proceed as in Experiment 108.

Experiment 114. Ammonium carbonate may be detected in a baking powder by mixing it with a little water, and suspending in the beaker, which should be covered with a watch glass, a piece of moistened red litmus paper. After a time this will become blue if ammonia is present.

Experiment 115. To test for lime in a sample of cream of tartar, in the absence of phosphates, ignite, dissolve the ash in water, with a little HCl, filter, and add an excess of ammonium hydroxid, and a few drops of ammonium oxalate. The formation of a white precipitate indicates the presence of lime (see Experiment 113).

It is essential that all the ingredients of which a baking powder is composed should be well dried before mixing. The reason for this is obvious, as without it a partial combination is liable to take place continuously. Of course there is a temptation to add more starch than is essential, but an amount of not over 20 to 25% is not considered excessive, and less than this is sufficient for the purpose.

HOMEMADE BAKING POWDER

An excellent powder for domestic use may be made as follows: —

	Lb.
Cream of tartar, fully dried	1
Cornstarch	$\frac{1}{2}$
Baking soda	$\frac{1}{2}$

These materials can be bought at a moderate price, and should be dried separately and *well mixed*, and then kept in a dry place.

2. FERMENTED BREAD

Raised bread is usually made from wheat or rye flour, which is made into a paste with water, salt, and yeast. There are several ways in which the ferment may be used.

(*a*) The first of these methods is by the use of yeast.

(*b*) The second is by the use of " leaven," or sour dough.

(*c*) The third is commonly known as the " salt-rising " process.

In all of these processes, however, the yeast germs bring about the fermentation, the only difference, as will be seen later, being the source from which the ferment comes.

(a) THE USE OF YEAST

In the ordinary method the yeast is mixed with a little warm (not hot) water and flour, or potatoes and salt, and thus what is called " sponge " is made. This is allowed to rise for some hours, and to it is added more flour, and water or milk. Fermentation proceeds, with a continual evolution of gas. The gluten which is in the dough retards the escape of the carbon dioxid, and the tension of the warm gas expands the little cells; then the dough is puffed up and becomes light and spongy. It is molded into loaves, and the loaves are set in a warm place until the expansion of the gases has raised them somewhat, and they are then baked in an oven heated to a temperature of from 350° to 570° F. The oven should not be too hot at first, as in this case the crust that is formed will prevent the interior of the loaf from being fully baked, or it will cause the loaf to crack open in an unsightly way from the expanding gases.

Yeast was known to the ancient Egyptians, and from them the Greeks and Romans learned its use. In the

raising of bread the conditions are favorable first for the breaking up of the starch by the diastase of the flour into a kind of sugar, and second, by the action of yeast a part of the sugar is changed into carbon dioxid gas and alcohol. This is represented by the following equations :—

$$\underset{\text{Starch}}{C_6H_{10}O_5} + H_2O = \underset{\text{Sugar}}{C_6H_{12}O_6}; \quad C_6H_{12}O_6 = 2\,\underset{\text{Alcohol}}{C_2H_6O} + 2\,CO_2.$$

Yeast requires for its growth, sugar, nitrogenous compounds, and mineral salts.

Much time and study has been given, by chemists, to the cultivation of pure yeasts, and to the cultivation of those varieties best adapted to bread and beer making. The variety best adapted to bread-making is said to be *Saccharomyces cerevisiæ.*

Brewers' yeast, which is one of the best to use for making bread, should be fresh and not soured. Compressed yeast is made from a by-product of the distilleries. " Top yeast " or bottom yeast may be used, but the former is considered more desirable for bread-making. This material is pressed and mixed with 5 or 6% of starch. It may be wrapped in tinfoil, while still somewhat moist, and shipped in a refrigerator. The addition of any considerable quantity of starch to these cakes is considered an adulteration.

For domestic use, yeast is prepared by the use of flour, water, a little salt, yeast, and some mashed potatoes. To this is sometimes added water in which hops have been boiled, and the whole is allowed to ferment for about 6 hours. This yeast will keep well in a cool place, but in a warm place it ferments rapidly and is soon sour. A yeast can also be made by preparing a mixture of flour, water, and salt and then, without adding the yeast, allowing the

germs to get in from the air. After a few days, if the mixture is kept in a warm place, a product will be obtained similar to the material made by the use of yeast.

Sometimes the yeast plant is mixed with corn meal, and the dried mass is put upon the market under the name of "yeast cakes." These cakes, which will keep almost indefinitely, only need to be soaked in warm water to be ready for use.

(b) THE USE OF LEAVEN

In the use of the leavening, or sour-dough process, which has been practiced for hundreds of years, some of the dough that has been left over from one batch of bread is used in raising the next. "A little leaven leaveneth the whole lump." This leaven should be kept in a cool place, lest other microörganisms besides yeast plants get into the dough, and even then there is often a secondary, or lactic, fermentation, so that the resulting bread is sour, or has a disagreeable taste. Since compressed yeast cakes are to be purchased almost everywhere, this process of raising bread is not used as much as formerly. It is chiefly used in the raising of rye bread and other coarse forms of breadstuffs.

(c) THE SALT-RISING PROCESS

The salt-rising process depends on the fact that there exist in the various ingredients, especially in corn meal, certain bacteria which will grow at a temperature *above* that which is favorable for yeasts and molds. H. A. Kohman [1] has found it practicable to isolate these bacteria, so that under the right conditions they can be used

[1] *J. Ind. and Eng. Chem.*, Vol. 4, 1912.

as a "starter." Salt, corn meal, and baking soda are stirred into milk heated to boiling. This "sponge" is allowed to stand from 12 to 15 hours, and is then mixed with flour and water, and the dough is kept at a temperature of 110° F. for some time. It is then molded into loaves and baked. Salt-rising bread is finer grained than yeast bread, and has a peculiar and characteristic odor, which is due, no doubt, to the lactic fermentation which has taken place.

CAUSES THAT AFFECT FERMENTATION

Organic acids assist fermentation.

Mineral acids will destroy the ferment.

Alkalies stop fermentation.

Twenty per cent of alcohol stops fermentation.

Drying does not stop fermentation.

Boiling destroys the ferment.

A low temperature hinders fermentation, but does not destroy the ferment.

Alcoholic fermentation takes place best at a temperature of from 9° to 25° C. (from 48.2° to 77° F.). The yeast plant grows very rapidly, by a process of "budding"; so that often one cell will multiply to eighty in nine hours. Above 30° C. butyric fermentation sets in, and the products are still further changed. Ferments may be kept out of a fermentable liquid, or medium, by first sterilizing it by heat, then protecting it with a wad of sterilized cotton, or even by a capillary tube that is very much twisted.

If the process of fermentation is allowed to go too far, the sugar, or some of it, is further decomposed into lactic acid, thus: —

$$C_6H_{12}O_6 = 2\ C_3H_6O_3,$$
Lactic Acid

and the dough becomes sour. This may also take place, in some cases, by the formation of other acids in the mass, as the moist dough is a good medium for the growth of various ferments besides the yeast plant.

MAKING GOOD BREAD

Some of the most important things to be noted in the making of good bread: —

1. Thorough kneading, in order to distribute the sponge or yeast well through the mass. Lack of attention to this will cause the bread to be coarse grained, and to have large holes distributed irregularly through it.

2. The dough should be allowed to rise sufficiently, so that the carbon dioxid gas and the alcohol that are formed in the process of fermentation may have an opportunity to raise the loaf. In this process, the soluble albumen and globulin of the flour become insoluble, and can no longer be separated from the starch. It is probable that some of the gliadin is rendered soluble. The starch is partly changed to soluble carbohydrate, and partly to carbon dioxid and alcohol.

3. In the process of baking, the heat should not be too great, at first, but time should be given for the dough to dry throughout the whole mass, for the cell walls to become firm, and for the starch to become well cooked. As this heating goes on, while the inside of the loaf is not usually heated above 100° C., the outside will gradually get hotter, dextrin and some caramel will be formed, and the yeast cells will be killed by the heat. Baking renders the starch more soluble, and hence digestible. The dex-

trin that is formed is sweeter than starch, and as it is more soluble, there is reason in the belief that it is a better food for invalids than the crumb. It is also necessary to masticate toast thoroughly; that is, if it is eaten dry, so the process of digestion will be further assisted.

Before putting the loaves into the oven, they are sometimes moistened on the surface, to assist in the prompt formation of a crust that shall restrain the loaf in its tendency to expand too rapidly. If steam is injected into the oven during baking, it produces a glazed surface on the loaf. The steam given off from the bread when it is first put into the oven acts in the same way. In baking, the heat also expands the gases given off, and this assists in puffing up the dough.

4. The process of fermentation should not be allowed to go too far. If we knew the exact amount of lactic acid formed in any case, we might add sufficient sodium bicarbonate, known as "baking soda," to neutralize it, but as we cannot in practice do this, it is better to regulate the temperature carefully, so that the dough does not get too light. If too much baking soda is added, the loaf will be yellow in color, alkaline, and unwholesome.

LOSS IN BAKING

In the process of baking, bread will lose from 15 to 20 % of its weight. This loss is due to the escape of carbon dioxid gas, water, and alcohol. Elaborate attempts have been made to collect the alcohol that escapes during the process, but they have so far been failures. There is no small amount lost, however, as Liebig estimated that in Germany alone 12,000,000 gal. of alcohol disappeared yearly in this industry. There

remains in the fresh bread, after baking, about 2 parts of alcohol per 1000, and after a week this amount is diminished to 1 part per 1000. One author estimated that 40 2-lb. loaves contained as much alcohol as a bottle of port wine.

BAKING

A good method for testing the heat of the oven is to throw into it some dry flour, and if it soon becomes brown the temperature is sufficiently high. The flour should not burn, of course, but dextrin should be formed. The question naturally arises, Why does not the bread burn at this high temperature? If we remember the large amount of moisture and alcohol that are evaporated during the process of baking, it is easy to see that for the time, at least, much of the heat is used up in driving off these substances, and it is not till later in the operation that the temperature is high enough to change the starch of the outside of a loaf into dextrin.

In large bakeries the oven is heated to a temperature a little above that required to bake the bread (500° F.) at first, and when the bread is put in the temperature falls, on account of the amount of cold material that has come into the oven, and then gradually rises again, even if no more fuel is added. Just before a batch is baked more fuel is added, to raise the temperature at the close of the operation, and to prepare the oven for the next lot.

In the old-fashioned way of baking in a brick oven, a fire was built in the oven, and, when the bricks became hot, the fire was removed, the ashes swept out, and the bread was baked with the heat that the walls of the oven had retained. This method of baking is still used on a large scale, especially in England. The Dutch oven, an iron

pot, with a cast-iron cover, which is kept hot by coals above and below, is used for baking where no better appliance is at hand. In most large bakeries crackers are baked on the swinging shelves of a horizontal cylinder that slowly moves above a smokeless fire. About twenty minutes is required for baking a batch, which is put into the oven at the same point where the previous lot was removed. The swinging shelves are so arranged that the heat is uniformly distributed under the revolving wheel, and by a mechanical arrangement any point of this wheel may be brought in front of the charging door.

FRESH *VS.* STALE BREAD

That there is a difference between fresh bread and that which is several days old is very apparent. What this difference is was for some time a question. It was formerly said that this difference was due solely to the loss of water, but that is proved not to be the case, as there is nearly as much water in bread after several days as when the bread is fresh, and if stale bread is reheated it becomes for the time fresh again. It has been suggested that in fresh bread some free water is present, which becomes united with the starch or gluten as the bread grows stale, and that reheating sets it free again. It has also been stated that the difference is only a "molecular one." Stale bread still contains about 45% of water. The true theory may be that as bread dries the fibers gradually approach nearer to each other by shrinkage, and the walls of the thousands of pores are consolidated, and the size of the pores is thus increased. When the stale bread is heated, expansion occurs; by the conversion of some of the water into vapor, the adhesion between the fibers is

broken up, drawing them apart in the direction of the least resistance, producing an apparent diminution in the porosity.

A great impetus was given to the baking industry by the Vienna Baking Exhibit at Philadelphia, in 1876. Bread furnished by the bakers at present is a better imitation of the domestic bread, and hence is more palatable, than that formerly made.

COMPOSITION OF BREAD

From 100 lb. of flour it is possible to make 135 to 150 lb. of bread, or, it may be stated, that from $\frac{3}{4}$ lb. of flour it is possible to make 1 lb. of bread. If dry flour contains 16 % of water, when this is made into bread it gives the composition: flour, 84 parts; water, 16 and 50, making 150 parts. The water is retained by the gluten cells. A flour that contains only a little gluten will not make a good strong dough. Bakers take advantage of this, and to make a strong dough, that will rise well, they mix hard and soft wheat in such proportions as will give a dough that is rich in gluten. When considered with reference to the amount of gluten, the following analysis of bread is of interest: —

	Per Cent
Water	40
Gluten	7
Starch, sugar, and gum	51
Salts	2
	100

From Bulletin 13, Part 9, of the Bureau of Chemistry, United States Department of Agriculture, the following analyses are quoted: —

	Moisture	Proteins N × 6.25	Ether Extract	Crude Fiber	Salt	Ash	Carbohydrates, excluding Fiber
Vienna bread	38.71	8.87	1.06	.62	.57	1.19	53.72
Homemade bread . .	33.02	7.94	1.95	.24	.56	1.05	56.75
Graham bread	34.80	8.93	2.03	1.13	.69	1.59	53.40
Rye bread	33.42	8.63	.66	.62	1.00	1.84	56.21
Miscellaneous bread . .	34.41	7.60	1.48	.30	.49	1.00	56.18
Biscuits or crackers . .	7.13	10.34	8.67	.47	.99	1.57	73.17
Rolls	27.98	8.20	3.41	.60	.69	1.31	59.82

For comparing the " crumb " and the " crust," we have the following analyses, calculated from anhydrous bread: —

	Nitrogenous	Dextrin and Sol. Starch	Sugar	Fat	Starch	Water in Original Bread
Crumb . .	11.29	14.97	4.17	1.68	67.87	40.60
Crust . . .	10.97	16.09	4.15	.71	68.07	13.00

A great variety of products is now put on the market by the cracker factories. These include such brands as " pilots," made without yeast, but with hot water, lard, flour, and salt; " sodas," made by the use of flour, yeast, and lard, or cottonseed oil; " wafers," made by the use of butter, sugar, vanilla, flour, and baking powder; and " snaps," made from sugar, flour, lard, baking powder, and ginger.

NUTRITIVE VALUE OF BREAD

Starch alone is not sufficient to sustain life, for the nitrogen, to assist in building up the tissues of the body, must

also be obtained from some organic source. One fact not to be lost sight of is that man does not live "by bread alone." He does make use of a large amount of nitrogenous food, in the shape of beef, milk, eggs, etc.; so it is not absolutely necessary that the wheat or other grain should furnish sufficient nitrogenous material to sustain life. In the modern processes of milling, the first and second grades of flour are really rich in proteins. The bran that man may have discarded is used by the lower animals for food, and so in the beef, pork, and mutton we get the proteins that are necessary. Man chooses to allow the animal to do this concentrating for him, and thus he has the advantage of a mixed diet.

Some so-called Infants' Foods are principally starch, and when fed to infants are practically useless, as the starch-converting ferments of the pancreatic juice are not secreted till about the end of the first year.[1]

Bread must be regarded as one of the most nutritious of foods. It yields to the blood a large quantity of carbohydrates, considerable proteins and mineral salts, and but very little fat. When it is eaten with butter, the deficiency of fat is made up; we also eat bread with meat, and thus the lack of proteins, which would be necessary to make bread a perfect food, is supplied. Bread and milk is a better balanced ration than bread alone, as the milk furnishes both protein and fat to supplement the deficiency.

VARIETIES OF BREAD

Many experiments have been made, and much has been written, on the relative value of white bread and bran, Graham, and whole-wheat bread. Even if sometimes

[1] Cotton's "Anatomy, Physiology, and Hygiene of Childhood."

the whole-wheat bread does contain more proteins, they are in such a form that they cannot be readily acted upon by the digestive juices and so there seems to be less absorption of them than in the case of white bread. Artificial digestion experiments confirm this opinion.[1] Then, too, the coarser breads are liable to produce some irritation in the intestines, and this prevents perfect digestion and absorption of the food.

Graham flour is properly made from thoroughly cleaned wheat, ground, but not bolted. Some millers claim that they can get better results by the use of the old style burr stones than by the roller-mill process. The term " entire wheat " flour is a misnomer, as in this product the outer or branny covering of the grain has been removed and is not a constituent of the product.

Many attempts have been made to perfect a flour, richer in proteins, and better adapted than ordinary flour to sustain animal life. Such attempts are the mixing of pease meal and of casein with flour, and the use of milk in making the bread. There are also many so-called " germ flours " on the market, and if it is proved that they are well absorbed, this may help to solve the problem.

It is probably true that the second grade of flour will make a more nutritious bread than the highest " patent." If stale bread is rebaked, it becomes, for the time, fresh again. It is a well-known fact that stale bread has the reputation of being more wholesome, and this is founded on reason, because fresh bread has a tendency, when masticated, to roll together in doughy masses that are not readily attacked by the digestive fluids. Stale bread retains its porosity, to a large extent, while it is being mixed with the saliva.

[1] Snyder, U. S. Dept. Agric., O. Ex. Sta., Bul. 101.

In addition to wheat bread, a brown bread, made from wheat and Indian meal, or rye and Indian meal, is much in favor in some localities. The addition of rye or wheat to corn meal assists very much in the raising of the dough, because there is not sufficient gluten in the meal to make a strong dough that will retain the gas bubbles. The properties of flour from the other grains are discussed elsewhere.

BAD BREAD

Bread may be bad for several causes. Among these may be mentioned the following: —

1. It is bitter, from an abnormal growth in the flour, or from the grain being partly spoiled.

2. It is heavy, from being imperfectly baked, or from the use of poor yeast, or from not being allowed to rise sufficiently before being placed in the oven.

3. The flour may be deficient in gluten, from bad milling, or from the "growing" of the wheat before it was ground. In this case light bread cannot be made, as the dough does not possess sufficient tenacity to cling together and hold the gases that are evolved.

4. The bread may be sour from overfermentation, or, what amounts to the same thing, from allowing the fermentation to proceed at too high a temperature. There is no excuse for this, as it simply denotes carelessness or ignorance.

5. Bread may be moldy if it is kept in a damp place or if it is kept too long. This mold is due to the growth of microscopic plants that find the moist bread a fertile medium. These molds may be white, green, orange, or black. They are supposed by some to be poisonous and to produce severe disorders, but even if that is not the case they render the bread unfit for use.

The center of a loaf of bread is sometimes the feeding ground for these lower organisms,[1] especially in very warm weather, because the heat of the oven has not been sufficient to entirely sterilize the interior, and so the bread spoils. The texture of the loaf will be changed so that it will be stringy and a disagreeable odor is emitted.

6. The bread may be of a dark color, though not made from lower grades of flour. This is due to the change that has taken place in the grain or in the flour by its being wet and allowing the starch to change to dextrin, gum, or sugar. This is practically what takes place in the malting of grains.

ADULTERATION OF FLOUR AND BREAD; COMPOUND FLOUR

The most common adulteration of wheat flour in the United States is the addition to it of other flours, especially that of corn and possibly rice. This can be readily detected by the use of the microscope. The government requires all such flours to be labeled "Compound," and to pay a revenue tax of 4 cents per barrel.

As white bread commands a better price than dark, and as there is always a greater demand for white bread, various attempts have been made to make a white bread from a low grade of flour. Substances used for this purpose formerly constituted the chief adulteration to which flour was liable. In Europe copper sulfate and alum had been used, but in many countries their use is now prohibited by law. Even so small a quantity as 1 part of copper sulfate in 10,000 parts of flour is said to be sufficient to enable the baker to make a white bread from a low grade of flour. The use of this chemical is condemned

[1] *Chem. Abs.*, II, p. 1168.

on account of the poisonous nature of the salts of copper.

Liebig states that the alum makes insoluble the gluten that has before been rendered partially soluble by the acetic and lactic acids that were developed in the process of fermentation. In this way the change from starch to dextrin or sugar is arrested. There is a difference of opinion as to the effect of alum upon the system, but the most reliable testimony is that as the loaf is not heated much above 100° C. the alumina will not be rendered insoluble. In that case it will go into the circulation and thus tend to injure the system. The amount of alum used is not over $1\frac{1}{2}$ to 3 ounces to 100 lb. of flour.

Experiment 116. To test for copper sulfate some of the bread may be ignited in a porcelain dish with nitric acid, and the ash that is left is boiled with a few drops of nitric acid, diluted and filtered. To one half of the filtrate an excess of ammonium hydroxid is added, and a blue coloration will indicate the presence of copper. The other half should be neutralized with sodium hydroxid, made slightly acid with acetic acid, and tested by means of potassium ferrocyanid. The appearance of a reddish color indicates copper.

Experiment 117. To detect alum in flour, the logwood test has been found very satisfactory. Fifty grams of flour are mixed with 50 cc. of distilled water, and to this is added 5 cc. of a *freshly prepared* logwood solution, and the whole is made alkaline with 5 cc. of a solution of ammonium carbonate. With as small a quantity of alum as $\frac{1}{10{,}000}$ the color of the solution will be lavender blue, instead of a dirty pink. It is well to set the mixture aside in a warm place for 2 hr., and notice if the blue color is permanent.

Experiment 118. To test for alum in bread, add to 50 cc. of water 5 cc. of logwood solution and 5 cc. of ammonium car-

bonate solution. Soak about 10 g. of the crumb in this for 5 minutes, pour out the liquid, and dry the bread at a gentle heat. If alum is present the lavender or dark blue color will appear, but if the bread is pure it will turn to a dirty brown color. As alum is not often used in flour in this country, these tests may be made with some of the "self-rising" flours, which usually contain alum, or upon cakes made from this flour.

Ergot is sometimes found in flour, especially in that made from rye. This is due to the "spurred rye," as it is called, or really to a fungus growth that is found on the grain. It is poisonous, and sometimes has proven injurious to the lower animals.

There is very little danger, in the United States at least, of the adulteration of flour with clay, chalk, terra alba, or any such materials.

Recently the process of bleaching flour has been introduced. For this purpose oxides of nitrogen, hydrogen peroxid, or chlorin gas are generally employed. The object of bleaching flour is to enable the miller to make more white flour from the grain. Opinions are divided as to the wholesomeness of flour treated in this way, but the consumer is at least entitled to know from the label if the flour has been bleached.

Experiment 119. Put a sample of flour into a large bottle and cover with gasoline. If the flour is unbleached the solution becomes yellow, if bleached it remains colorless.

CHAPTER XV

PREDIGESTED AND SPECIAL FOODS

INFANT'S AND INVALID'S FOOD

Foods for infants and invalids are made up largely of cereals which are modified by application of heat, by digestion with malt or diastase, and by malting the cereal, adding cream or milk, and evaporating. Among those prepared by heat alone may be mentioned Blair's and Imperial Granum; Mellin's and Horlick's foods are representatives of the class that is made by mixing wheat flour with malt and a little potassium carbonate, moistening with water and heating at a fixed temperature for several hours.[1] The starch of the flour is by this process changed to maltose and dextrin, which are soluble substances. In making the malted cream foods, the flour is made into dough, baked, ground, and malted, mixed with cream, and evaporated to dryness in a vacuum. Foods of this class, such as Malted Milk and Nestlé's Food, are richer in fat and albumen than the others mentioned.[2]

The following analyses quoted by Hutchinson give the composition of some of the well-known Proprietary foods: —

[1] Canadian Dept. of Inland Rev., Bul. 59.

[2] "Davis's Chemistry for Schools," p. 285, from König.

Name	Water	Protein	Fat	Carbohydrate	Mineral Matter
Dried human milk . . .		12.2	26.4	52.4	2.1
Horlick's malted milk . .	3.7	13.8	3.0	76.8	2.7
Carnrick's soluble food . .	5.5	13.6	2.5	76.2	2.2
Nestlé's milk food . . .	5.5	11.0	4.8	77.4	1.3
Mellin's food	6.3	7.9	trace	82.0	3.8
Ridge's food	7.9	9.2	1.0	81.2	0.7
Robinson's groats . . .	10.4	11.3	1.6	75.0	1.7
Robinson's patent barley .	10.1	5.1	3.9	82.0	1.9

BREAKFAST FOODS

Breakfast foods and " predigested " foods have recently been introduced, ostensibly to take the place of foods improperly prepared, and to assist digestion. That there is a popular demand for foods of this kind there is no doubt, but their extended use is only another illustration of the tendency in the United States to allow some one else to do the work of the household for us, even though the food thus prepared may be expensive and unsatisfactory. The statements made on the package usually have nothing to do with the value or digestibility of the food. The price at which they are sold also bears no relation to the weight of the package or the nutritive value.

In discussing the popular " breakfast foods " a prominent writer says : —

" This craving for something new to stimulate a jaded appetite, already spoiled by endless variety and bad combinations, has led to the manufacture of a cereal preparation for nearly every day in the year. No better comment on the laziness or willful ignorance of the American providers could be made than this. Little do the people know about wheat or cooking if they suppose that grain can be changed by manipulation in any kind of machine so as to give a

greater food value than was contained in the grain. While it is true that some of these preparations are far better than the half-cooked grains found on so many tables, the fact remains that it is the cook and not the substance which is poor. It is not always best to have food that is too easily digested.

" A predigested food is quickly absorbed into the circulation, and hence a small quantity causes a sensation of fullness and satisfaction, which, however, soon passes away and faintness results. This is especially true of the sugar and the dextrins. Frequent meals should go with these easily absorbed foods. This rapid digestion is the cause of much pernicious eating of sweets between meals, which satisfies the appetite for the time being and prevents substantial quantities of other foods being taken at the time when they are offered." [1]

It is well to note that the oatmeal sold in bulk is practically the same as that sold in packages, only the latter has been better protected from vermin and dust. It is true that oatmeal contains more protein and fat, and as far as the analysis shows, offers a better-balanced ration than most of the other foods, but that does not prove that it should be used exclusively as a breakfast food. The cereals — wheat, barley, corn, and oats — are the chief source for the manufacture of all these foods, but they are prepared by different processes.

The analysis of a few typical brands is as follows: [2] —

[1] Richards and Woodman, "Air, Water, and Food," p. 156.
[2] Slosson, Wyoming Exp. Station, Bul. 33.

	Moisture	Crude Protein	Carbo-hydrates	Fats	Crude Fiber	Ash	Retails at Cents per Lb.
Grape Nuts	8.00	12.73	73.78	1.57	2.02	1.90	$.13
Malta-Vita	8.93	11.84	73.19	1.55	1.82	2.67	.11
F. S. Rolled Avena . . .	9.68	18.42	60.85	6.88	2.22	1.95	.07½
Ralston's Health Breakfast Food	11.07	12.55	72.11	1.72	1.35	1.20	.07½
Pillsbury's Vitos	11.19	13.08	73.44	1.08	.58	.58	.07
Pettijohn's Breakfast Food .	10.43	12.11	71.08	2.50	2.30	1.58	.07
Quaker Rolled Oats . . .	9.40	17.55	61.56	7.20	2.40	1.89	.05
Shredded Whole Wheat . .	8.91	11.32	73.93	0.87	3.40	1.57	.11
Vigor	9.12	14.46	69.18	1.65	2.38	3.21	.15

From a study of the analysis of a large number of these foods, F. W. Robison [1] arrives at these conclusions: —

"1. The breakfast foods are legitimate and valuable foods.

"2. Predigestion has been carried on in the majority of them to a limited degree only.

"3. The price for which they are sold is, as a rule, excessive and not in keeping with their nutritive values.

"4. They contain, as a rule, considerable fiber, which, while probably rendering them less digestible, at the same time may render them more wholesome to the average person.

"5. The claims made for many of them are not warranted by the facts.

"6. The claim that they are far more nutritious than the wheat and grains from which they are made is not substantiated.

"7. They are palatable, as a rule, and pleasing to the eye.

[1] Robison, Michigan Agric. Exp. Station, Div. Chem., 1904.

" 8. The digestibility of these products, as compared with highly milled foods, while probably favorable to the latter, does not give due credit to the former, because of the healthful influence of the fiber and mineral matter in the breakfast foods.

" 9. Rolled oats, or oatmeal, as a source of protein and of fuel is ahead of the wheat preparations, excepting, of course, the special gluten foods, which are manifestly in a different class."

MACARONI

Macaroni, vermicelli, spaghetti, and other " pastes " are made in Italy, France, and Switzerland, from certain highly nitrogenous varieties of wheat. They have more recently been made in this country. The macaroni is made by mixing " semolina " — the hard, flinty part of the wheat grain — with the special wheat, making it into a paste, and pressing through the bottom of a cylinder pierced with holes. The tubes which come through the perforations are cooled, cut in lengths, and dried on screens.

The composition of macaroni, according to Church,[1] is: —

	Fine Variety	Cheaper Variety
Water	13.0	10.0
Albuminoids, etc.	11.1	13.5
Starch, etc.	73.8	70.8
Fat	.9	2.3
Cellulose	.4	1.4
Mineral matter	.8	2.0

[1] Church, "Food," p. 81.

Macaroni should be well soaked in water before cooking, and may very conveniently be served with cheese, which adds to its nutritive value. Sir Henry Thompson,[1] in speaking of macaroni, says that " weight for weight it may by regarded as not less valuable for flesh-making purposes in the animal economy than beef or mutton. Most people can digest it more easily and rapidly than meat. It offers, therefore, an admirable substitute for meat, particularly for lunch or the midday meal."

[1] Quoted from W. G. Thompson, "Practical Dietetics," p. 152.

CHAPTER XVI

SUGARS

HISTORY AND CLASSIFICATION OF SUGARS

Sugar was known at such an early age that the date of its discovery is lost. We hear of its use in India perhaps earlier than elsewhere. In Europe honey was used for sweetening purposes before sugar came into general use. The sugar cane was cultivated in the regions adjoining the Mediterranean Sea as early as 1148, in the West Indies in 1506, and on the North American continent in 1800. Sugar was first noticed as a curiosity, then it came into use as a medicine, and finally has become a necessary part of our diet. Sugar was at first confounded with manna, and was supposed to be the dried juice of a plant. As it was not well understood, physicians regarded it as having an injurious effect upon the system. Honey was thought to be more wholesome, because a "natural food." We find the price of sugar quoted at 45 cents per pound when it first came into use. The amount of sugar used in civilized countries is constantly on the increase.

The sugars have essentially the same food value as the starches, as the latter must be converted into dextrin or sugar in the process of digestion. As cane sugar must be changed into a form of grape sugar before being digested, the latter is often spoken of as a " predigested " form of food. Although sugar is an excellent energy producer,

and in fact stands at the head of the list, yet an over-indulgence in this food, especially in cane sugar, is sure to cause flatulent dyspepsia and other disorders.

Over 17,000,000 tons of sugar are consumed annually in the world, and English-speaking nations consume the most per capita. In 1910–11 the per capita consumption in England was 91 lb.; in Germany, 48 lb.; France, 43 lb.; in Italy, 10 lb.; Servia, 8 lb.; and in the United States, 79 lb. The per capita use of sugar in 1914 in the United States was 75 lb.

On account of their importance as food materials sugars should be thoroughly discussed, and their composition and relations to other nutrients should be well understood. In general the sugars are recognized by the fact that they are readily soluble in water; that they have a sweet taste; and that they rotate the plane of polarized light.

There are a large number of sugars known to the chemist, but up to the present time the property of sweetness has not been identified as belonging to any definite molecule or to any definite combination. In addition to the sugars, there are other substances that are sweet, as, for instance, the alcohols and the organic compound Saccharin, $C_7H_5O_3SN$, which is about 500 times as sweet as cane sugar. The addition of one part of saccharin to 1000 parts of glucose renders the latter as sweet as cane sugar. Saccharin is sometimes used to replace sugar for the use of diabetic patients, but it has no food value.

The sugars that are in common use may be divided into two general classes: the sucrose, or cane sugar, group, having the composition $C_{12}H_{22}O_{11}$, and the glucoses, or grape sugars, having the composition $C_6H_{12}O_6$. Sugars of both these classes are found under various names in a large

number of food substances. These two groups are also very intimately related, so that by " inversion," with heat and dilute acids, some of the members of the first group may be changed to those of the second group.

Sucrose, $C_{12}H_{22}O_{11}$

The most important members of this group are sucrose, maltose, and lactose. Sucrose, or cane sugar, occurs abundantly in roots, grasses, and stems of many plants, as well as in fruits. There are, however, only a few plants from which it is economical to make sugar. These plants are the sugar cane, the sugar beet, sorghum, the maple and birch trees, corn stalks, carrots, and sweet potatoes. About two thirds of the sugar, as estimated by Wiley, is made from the beet, and one third from sugar cane. The other sources are of so little importance that they need only be mentioned incidentally. Sugar obtained from either sugar cane, the beet, or any other of the sources mentioned has the same composition, and the chemist cannot recognize any difference between the products.

From 13 % to 20 % of sugar is found in the stalks of sugar cane; from 4 % to 15 % in the sugar beet; sometimes as much as 15 % in sorghum; and the sap of the maple tree contains a little over 2 % of sugar.

SUGAR CANE

Sugar cane belongs to the family of grasses, of which there are many varieties growing in tropical and subtropical countries, especially in the moist climate of islands and the seacoast. The sugar cane is successfully cultivated mainly in Cuba, the West Indies, Louisiana, the Philippines, Java, Brazil, and the Hawaiian Islands. The cane flourishes best where the mean temperature is from

75° to 77° F., but it grows fairly well where the mean temperature is not below 66° F. Sugar cane is propagated not by seeds, but by cuttings. The young cane sprouts from the roots each year, and in the United States usually three crops are gathered from one setting, so on each plantation one third of the space is set with new cuttings each year. In the West Indies, however, the sprouts that come from the old roots are cut for a series of years until at last the plants die, and are then replaced by fresh cuttings. There are two processes of extracting the juice from the sugar-bearing material. The first is by crushing in roller mills, and the second is by diffusion. The former process has been used more especially for making sugar from cane and the latter from the sugar beet.

MAKING SUGAR FROM SUGAR CANE

The average analysis of the ripe cane shows it to contain of sugar 18%, fiber 9.5%, water 71%; but the juice contains of sucrose 18%, glucose .30%, gums 1.40%, mineral salts .30%, water 80%.[1] By the best practice about 84% of the juice is extracted from the cane.

The cane is cut in the fall, and after being stripped and topped is passed through a "shredder," to tear it to pieces, then several times between heavy horizontal rollers, to extract the juice. The "begasse" or crushed cane left after pressing is burned as fuel under the boilers. The juice in Louisiana does not often contain over 14% of sucrose, but in Cuba it may run as high as 18%. The juice is passed through a screen to remove suspended matter, then nearly neutralized with milk of lime, and heated to coagulate the albumen. This is called "def-

[1] Thorp, "Outlines of Industrial Chemistry," p. 388.

ecation." The lime not only neutralizes the acid, which is quickly formed, and thus prevents it from " inverting " the sugar, or changing it to uncrystallizable sugar, but it unites with the nitrogenous matter and causes it to separate. The scum, which contains many of the impurities, is allowed to rise to the surface and is then filtered off and pressed to remove as much of the saccharine liquid as possible. The pressed filter cake may be used as a fertilizer. The juice is often treated with sulfurous acid, which is made by burning sulfur, to prevent fermentation and improve the color. The juice must, however, be left slightly alkaline to prevent inversion. The juice may also be filtered through bone black or animal charcoal in order to remove the color.

Formerly the saccharine liquid was evaporated in open pans, until it began to crystallize, then emptied into shallow tanks and stirred until it was cool. The mixture, which contained both molasses and sugar, was placed in hogsheads having holes bored in the bottom, so that the molasses could drain out. By this process a sugar called " muscovado " was produced, which contained from 87 to 90 % of sucrose. The molasses obtained in this way was of good quality, but the process was not economical, as so much of the sugar was " inverted " in boiling.

In the modern sugarhouse the juice is first concentrated in " triple-effect " evaporators, which utilize the steam given off from one pan to assist in heating the next, and are therefore very economical; then the juice, which in this way is much concentrated, is run into the vacuum or " strike " pan. Usually the entire system of evaporation is heated by exhaust steam, and this conduces greatly to the economy of the process.

In the vacuum pan the juice is heated by steam coils and

the vapor is pumped off, thus reducing the pressure so that the sirup will boil at 150° to 180° F. instead of 230° to 250° F., which would be the case in the open pan. After the sugar has boiled to "grain," or until it begins to crystallize, some more sirup is admitted to the pan and crystals of sugar are gradually "built up" until a sufficiently large charge is obtained. A vacuum is maintained on the pan during the entire operation.

The mixture of molasses and sugar which is then drawn out of the vacuum pan is called *masse cuite*. A part of it is run directly into the "centrifugals," and the rest into a "mixer," where it is constantly stirred by mechanical means, until there is an opportunity to run it into the centrifugals. The latter revolve on a perpendicular axis at the rate of about 1200 times per minute. The outside or perpendicular wall of the drum is perforated, and by the rapid rotation the sirup "flies off" into the space outside the drum and runs into a receptacle below. The top of the drum is open to facilitate charging and washing, and the charge can be dropped out at the bottom, when the sirup has been separated from the sugar. The sugar while in the centrifugal may be washed by throwing into it while running a small quantity of water or a saturated solution of pure cane sugar.

The liquid that has run through the centrifugal together with the washing is defecated and again boiled down, forming a second *masse cuite*, from which a "second sugar" is obtained, and the process is sometimes repeated to obtain a third or even a fourth *masse cuite*. The second sugar is often mixed with the concentrated juice before it is run into the vacuum pan, to save time in "building up" the grain of the sugar. The impure molasses finally obtained is run into a cistern and worked up later in the

season in various ways. Recently it has been found to be economical to mix some of this molasses with the feed of the mules which are employed on the plantation.

The object of the sugar boiler is to obtain as large a quantity of cane sugar, and as little uncrystallizable or "invert" sugar as possible, since the impure molasses is of little commercial value.

The total production of sugar from the sugar cane in the United States in 1914 was about 247,000 tons.[1]

MAKING SUGAR FROM THE SUGAR BEET

It was in 1747 that Marggraf, a German chemist, announced that it was possible to obtain a sugar from beet juice which was identical with that obtained from the sugar cane. Achard, a pupil of his, actually erected a factory and made some beet sugar, but, as only 2 or 3 % of sugar could be extracted from the beets, it was not a commercial success. Napoleon I, in 1806, caused a bounty to be offered for beet sugar, and thus the manufacture was greatly stimulated. At first the beet contained only 6 % of sugar, but it has been improved so much by cultivation that it now often contains as high as 15 %. The other constituents of beet juice embarrassed the sugar boiler greatly for some time, but the process of manufacture has been so much improved that now these very impurities have been made a source of profit.

Although several methods have been used for extracting sugar from the beet, the "diffusion" process has been the most successful. According to the German method, the beets are cut into fine chips, and are then put into a series of large iron vessels, where they are extracted with warm

[1] Year Book, 1915, Dept. Agric.

water. The " battery " of diffusors is so arranged that the sweet water, heated to 60° C., may be circulated from one vessel to another, until the sugar is practically all removed from the chips. These are then dropped out of the cylinder. It is again filled with fresh chips, and so connected as to be made the last of the series of diffusors through which the juice is circulating. The exhausted chips are used as cattle food, as they are rich in nitrogenous matter. After the water has remained in contact with one lot of material for 20 minutes, it is drawn through a juice warmer before it is brought into the next diffusor. Although considerable water is used in this process, and the juice must be concentrated somewhat more than when extracted by crushing, yet the juice is so much more free from foreign nitrogenous substances that the diffusion process can be used with greater economy and succcess. All but 0.5 % of the sugar is extracted.[1]

The crude juice, which contains about as much sugar as the original beet juice, is heated to coagulate the albuminoids, and then lime is added to saturate the free acids, and assist in throwing down organic matter. Carbon dioxid gas is made to pass through the solution, and the latter is then forced through the filter press. Sometimes this operation of " carbonation " is repeated. Then the juice usually goes to the bone-black filters. Sometimes the treatment with lime and carbon dioxid gas, and sulfurous acids, purifies the juice so that no subsequent treatment with bone black is necessary. Special care and treatment is required to make from the sugar beet a fine crystalline sugar which has no unpleasant taste or odor.

The molasses obtained by this process is boiled down for a second sugar and a second molasses. As the latter

[1] Thorp, "Outlines of Industrial Chemistry," p. 393.

contains about 40 % of sugar that cannot be crystallized, this is usually recovered by treating with quicklime, probably forming a tricalcium saccharate,[1] $C_{12}H_{22}O_{11}$, 3 CaO. This latter salt is filter-pressed to separate the precipitate from the sirup and impurities, and this precipitate is used instead of lime in the defecation of fresh juice, or it may be decomposed by passing carbon dioxid into it. In 1915–1916, 862,000 tons of beet sugar were made in the United States.[2]

MAPLE SUGAR

The manufacture of sugar from the sap of the hard maple, *Acer saccharinum*, is quite common in the extreme Northern states and in Canada. The sugar season is limited to 6 or 8 weeks in the spring. The sap is drawn from the trees by "tapping," or making an incision through the bark, and arranging a spout to carry the juice to a receptacle below. This sap is then concentrated in shallow pans over an open fire, skimmed, and strained. Good sirup contains about 62 % of cane sugar, with varying amounts of invert sugar. Maple sugar contains about 83 % of cane sugar.

On account of the agreeable taste, which is due to certain characteristic substances, the maple products always command a high price in the market. There is therefore a temptation to imitate these products, or adulterate them. Brown sugar, especially, is often melted with inferior maple sugar, while maple sirup is adulterated with glucose, molasses, or refined sugar. Hickory bark is said to be used as a flavoring material in the imitation maple sugars. It is not difficult for the experienced chemist to detect the spurious article.

[1] "Industrial Chemistry," Rogers and Aubent, p. 663.
[2] Ann. Rep. Dept. Agric.

SORGHUM SUGAR

The juice of the sorghum (*Andropogon sorghum*) has been used for a long time in the United States by the farmers as a source of a cheap sirup, and the United States Department of Agriculture at one time carried on very extensive experiments, looking to the possibility of making a crystallizable sugar from sorghum. The cane has been improved so that it often contains 15 % of sugar. Many of the difficulties have been overcome by the use of the "diffusion process" and improved methods of purification of the juice. Although a good quality of sugar can be made, yet the manufacture can hardly be called a commercial success, and practically no sugar is made from sorghum.

MOLASSES

Molasses is of various grades, and contains the uncrystallizable sugar, some cane sugar, gum, coloring matter, and mineral salts. Where the drippings from the vessel from which the "first" sugar crystallizes are used as molasses, we have a very pure product. Since the lower grades of sugar are made by evaporation of the drippings and washings of the several crystallizations, they contain more impurities and more moisture than does granulated sugar, and it is a question whether they are really cheaper. It is probably on account of its ready solubility in the mouth that we get the impression that the impure sugar is sweeter.

SUGAR REFINING

Since much of the sugar raised on the plantations is put on the market in its "raw" condition, it must be refined

or purified before it is fit for use. Sugar refineries are usually situated in the large commercial centers, in this country at New York, Philadelphia, New Orleans, and San Francisco. The buildings are very high, so that advantage can be taken of gravity in handling the product. The raw sugar is partially dissolved in molasses in large vats, or " melters," placed below the floor of the basement. The *masse cuite* thus formed is run directly into the centrifugals, where it is slightly washed. The sugar thus obtained is " melted " in warm water, strained from the coarser particles of dirt, and pumped to the top of the building.

The solution may be " defecated " by boiling with lime, clay, alum, calcium phosphates, or with fresh blood from the packing house. It is then conveyed to " bag filters," made of heavy cotton twill, from 5 to 8 ft. long. Here the refuse that would not settle in the defecating tanks is collected. The liquor, which is now clear, but of a brownish color, is run into the " bone-black filters." These filters are long cylinders, often extending through several stories, fitted with a perforated bottom over which a blanket is spread, to prevent the bone black, with which the cylinder is filled, from falling through.

The sugar solution is allowed to trickle slowly on to this filter, and to remain for about 24 hours in contact with the bone black; the product first drawn off is the purest. When the bone black is exhausted, it is washed with water, which, of course, is saved, and the bone black is " revivified " by being burned in closed retorts. The bone black, when it is cold, is sifted and the dust is sold for the manufacture of fertilizers.

The colorless liquor is then ready to be concentrated in the " vacuum pan " previously described (p. 239). When

the *masse cuite* has crystallized sufficiently to make "loaf sugar," it is run into conical sheet-iron molds having an opening at the bottom, and the sirup runs off. Then a saturated solution of sugar is poured on the top of the "sugar loaves" to wash out the uncrystallized material. This process of drainage and drying may, however, be much shortened by placing several cones at a time in a centrifugal, and "throwing out" the sirup by rapid rotation.

A modern process of making loaf sugar is to warm the granulated sugar from the centrifugals with a saturated solution of pure sugar or with a thick sugar sirup, and to press this mixture into molds where it is allowed to harden.

Experiment 120. To show the action of bone black, dissolve about 30 g. of brown sugar in warm water, add at least 25 g. of bone black, and after shaking the mixture for some time, filter. A colorless filtrate should be obtained. The operation may be repeated with the filtrate if it is not colorless.

COMMERCIAL SUGARS

To make granulated sugar directly, the mixture of sugar and sirup, frequently 3500 pounds in a charge, is drawn off from the vacuum pan into a mixer, where it is stirred while cooling to prevent the grains from sticking together. The sugar and sirup are separated in the centrifugal, as in the case of making raw sugar, and the sugar is washed with fresh water. It is then conveyed to the "granulator," which is a rotating cylinder, set at a slight incline, and heated by steam. Here the sugar, which enters the upper end, is dried, and the grains are separated one from another, and then pass through a series of sieves, and are finally run into barrels for shipment. The sirups obtained

in the refining process may be again filtered through bone black, and boiled to make lower grades of sugar, or they may be mixed with glucose and put on the market directly as table sirups.

To make the granulated sugar from loaf sugar, the cones are crushed and sifted, and the crystals passed over a heated table into the packing barrels. Usually a little "ultramarine" is added to the sugar to correct the slightly yellow color. Although this coloring matter is not injurious, yet in some manufacturing processes it will be found to give a disagreeable odor to the sirup, on account of the decomposition of ultramarine by acids.

Powdered or pulverized sugars are made from the same stock as the granulated sugar, but it is ground and bolted in a mill similar to that used for making flour.

Cut sugar is made from the sugar loaves by sawing them in slices, and then cutting the slices into rectangular blocks by the use of a gang of small circular saws.

PROPERTIES OF CANE SUGAR

Cold water dissolves three times its weight of cane sugar.

Rapid boiling changes cane sugar to barley sugar, a transparent, non-crystalline mass, which has, however, the same chemical composition as sugar.

Experiment 121. Melt a sample of cane sugar in an iron pan or spoon, and examine the product, which is known as "barley sugar."

If the sample is heated to 400° F., a substance called "caramel" results. This material is extensively used in confectionery, and is a harmless coloring matter for beer and other alcoholic liquors.

Experiment 122. Heat a sample of sugar to a higher temperature than in Experiment 121, and dissolve the brownish substance so obtained in water. Notice the taste of the solution. When cane sugar is heated with an acid or with many salts and metals, the change known as "hydrolysis" takes place. This action is catalytic, as the "hydrolyte" does not enter into chemical combination with the products formed. This hydrolysis of cane sugar to an invert sugar can be expressed by the equation: $C_{12}H_{22}O_{11} + H_2O = 2\ C_6H_{12}O_6$.

Experiment 123. To 50 cc. of a fairly strong solution of cane sugar add 5 cc. of hydrochloric acid, and heat the solution gradually to 70° C., and keep it at this temperature for a few minutes. By this treatment the sugar is "inverted," and the presence of invert sugar may be determined by the Fehling's test, as noted in Experiment 98.

Experiment 124. As powdered sugar sometimes contains starch, a test may be made for this by boiling a sample of the sugar with water, cooling and adding a few drops of tincture of iodin. A blue coloration indicates starch.

The following table[1] gives the average composition of some common grades of sugar: —

Raw Sugars	Cane Sugar	Glucose	Water	Organic Matter	Ash
Good centrifugal	96.0	1.25	1.00	1.25	.50
Poor centrifugal	92.0	2.50	3.00	1.75	.75
Good muscovado	91.0	2.25	5.00	1.10	.65
Molasses sugar	88.0	2.80	3.00	3.50	2.70
Manila sugar	87.0	5.50	4.00	2.25	1.25
Beet sugar, 1st	95.0	—	2.00	1.75	1.25
Refined Sugars					
Granulated or loaf sugar	99.8	.20	—	—	—
White coffee sugar	91.0	2.40	5.50	.80	.30
Yellow sugar	82.0	7.50	6.00	2.50	2.00
Barrel sirup	40.0	25.00	20.00	10.00	5.00

[1] Thorp, "Outlines of Industrial Chemistry," p. 400.

THE FOOD VALUE OF SUGAR

The food value of sugar has been summarized as follows : [1] —

1. When the organism is adapted to the digestion of starch and there is sufficient time for its utilization, sugar has no advantage over starch as a food in muscular work except as a preventive of fatigue.

2. In small quantities and in not too concentrated form, sugar will take the place, practically speaking, weight for weight, of starch as a food for muscular work, barring the difference in energy and in time required to digest them, sugar having here the advantage.

3. It furnishes the needed carbohydrate material to organisms that have as yet little or no power to digest starch. Thus milk sugar is part of the natural food of the infant.

4. In times of great exertion or exhausting labor, the rapidity with which it is assimilated gives it certain advantages over starch.

AMOUNT OF SUGAR CONSUMED

The per capita consumption of sugar in the different countries for the year 1912–13 is reported to be as follows :[2]

	Lb.		Lb.
Denmark	98.96	Germany	48.95
England	95.52	France	48.41
United States	85.40	Norway	45.83
Switzerland	77.24	Russia	24.33
Sweden	57.09	Turkey	19.84
Netherlands	49.90	Italy	10.76

[1] Mary Hinman Abel, Farmers' Bul. 93, U. S. Dept. Agric.

[2] *The World Almanac*, 1915.

MALTOSE

Maltose ($C_{12}H_{22}O_{11} + H_2O$): this, together with dextrin, is made by the limited action of dilute acids or by the action of malt infusion on starch. This sugar probably does not ferment directly, but by the action of yeast its fermentation and conversion into dextrose go on simultaneously. It is an ingredient of commercial glucose, and is also the sugar produced by the action of the ptyalin of the saliva on starch, in the process of digestion.

The equation of changing gelatinized starch to maltose is as follows: —

$$\underset{\text{Starch}}{C_{18}H_{30}O_{15}} + H_2O = \underset{\text{Dextrin}}{C_6H_{10}O_5} + \underset{\text{Maltose}}{C_{12}H_{22}O_{11}}.$$

When either dextrin or maltose is heated with dilute acid, it is converted into dextrose. The hydrolysis in the case of maltose would be represented by the equation: —

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O = 2\ \underset{\text{Dextrose}}{C_6H_{12}O_6}.$$

(LACTOSE) MILK SUGAR

Lactose ($C_{12}H_{22}O_{11} + H_2O$) is made commercially by treating whey, a by-product in cheese making, with chalk and aluminum hydroxid, and after filtering off the precipitate thus produced, the filtrate is concentrated in a vacuum pan, and when sticks or strings are suspended in the sirup, the milk sugar crystallizes on them after some time.

This sugar is not as sweet as cane sugar, but it is very useful in "modified milk," in making dietetic preparations, and as a basis for the pellets used by homeopaths. In the ordinary souring of milk this sugar changes to lactic acid. On being heated with dilute acids lactose is inverted, forming dextrose and galactose (see reaction under Sucrose).

CHAPTER XVII

THE GLUCOSE OR GRAPE SUGAR GROUP, $C_6H_{12}O_6$

It will be noticed that under the general name "glucose" there are grouped a number of substances made by "hydrolysis" from starch, such as dextrose, and also substances such as levulose, which result from the inversion of cane sugar.

COMMERCIAL GLUCOSE

When the glucose is to be made from corn, the latter is steeped for some time in warm water, and the softened grain is crushed in a "cracker" to loosen the germs. The coarse meal passes to the "separators," where the germs, being light, float over the dam at the end of the tank. These germs are often used for making corn oil. The hulls and starchy matter are ground fine, and passed over "shakers" to remove the hulls. The starch suspended in water is now ready for the next process.

As previously stated, when starch is boiled with dilute acids it is converted into a mixture of compounds of the grape sugar group. The commercial process of manufacture is to treat the starch suspended in water, in the proportion of 10,000 pounds to 6 pounds, with hydrochloric acid. Closed "converters" are used in this process, and in this case the liquid is boiled under pressure.

When the process of conversion has been carried far enough and a test shows that no starch remains, the

liquor is neutralized with sodium carbonate, thus producing sodium chlorid, and the glucose solution is then decolorized by passing through bone-black filters. The solution is filtered through bag filters or a filter press. Concentration in the vacuum pan is then effected. Some manufacturers filter several times through bone black, and some use sulfur dioxid gas to bleach the product and arrest fermentation.

The process of hydrolysis would in part be represented by the equation: —

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6.$$

A number of intermediate products are formed.

When *glucose* is the product desired, the conversion of the starch is arrested while there is still considerable of the uncrystallizable dextrin in the product. This gives a heavy sirup. If the conversion is more complete, and the concentration is carried further, the product is a solid known as "*grape sugar.*"

The composition of the two products described is as follows: [1] —

	Glucose (liquid)	Grape Sugar (solid)
Dextrose	34.3% to 36.5%	72.0% to 99.4%
Maltose	4.6% to 19.3%	0% to 1.8%
Dextrin	29.8% to 45.3%	0% to 9.1%
Water	14.2% to 17.2%	.6% to 17.5%
Ash	.32% to .52%	.3% to .75%

Glucose mixed with molasses is frequently used in the manufacture of table sirups; in beer to take the place of malt; in the manufacture of confectionery, of artificial honey, and of maple sirup, jellies, jams, vinegar, wine, etc. From some experiments made by the author, glucose is shown to be three fifths as sweet as cane sugar.

[1] Leach, "Food Inspection and Analysis," 3d ed., p. 576.

As to the healthfulness of glucose, the committee of the National Academy of Science, to whom this question was referred some years ago, and from whose report many of the facts are gathered, say that there is no evidence of ill effects from its use.

The report concludes thus: "First, the manufacture of sugar from starch is a long-established industry; scientifically valuable and commercially important.

"Second, the processes that are employed at the present time are unobjectionable in their character and leave the product uncontaminated.

"Third, the starch sugar thus made and sent into commerce is of exceptional purity and uniformity of composition, and contains no injurious substances.

"Fourth, having at best only two thirds the sweetening power of cane sugar, yet starch sugar is in no way inferior to cane sugar in healthfulness, there being no evidence before the committee that maize or starch sugar, either in normal condition or fermented, has any deleterious effect upon the system even when taken in large quantities."

The glucoses, maltose, and milk sugar reduce Fehling's solution, but starch paste must be converted by acid, and cane sugar must be inverted before testing.

Experiment 125. Use a thin starch paste prepared as in Experiment 92. To 200 cc. of this, add about 20 cc. of dilute hydrochloric acid, and boil for 15 min. Neutralize the solution with NaOH; cool and test a portion, 1st, with iodin for starch; 2d, with Fehling's solution for dextrose. There may be some dextrin present, in which case a purple color will be obtained by iodin.

Experiment 126. Test a sample of commercial "grape sugar" for starch with iodin, and for a reducing sugar by Fehling's solution.

Experiment 127. Macerate some raisins with water, filter the solution, and test a portion for grape sugar or invert sugar by Fehling's solution.

Experiment 128. Crush an apple and squeeze the juice through a cloth, filter this, and test for the invert sugar. The sugar of fruit is usually invert sugar, and this, like dextrose, has a reducing action with Fehling's solution.

Experiment 129. Test a dilute solution of pure honey for a reducing sugar by Fehling's solution.

Experiment 130. As hydrochloric acid is now so generally employed in making glucose, test a dilute solution of glucose for a chlorid by making slightly acid with nitric acid and adding a few drops of silver nitrate.

Experiment 131. Repeat the above experiment, using a dilute solution of honey.

INVERT SUGAR

Invert sugar is of importance, since it results from the inversion of cane sugar, and as it occurs in honey and many fruits. It is a mixture of equivalent proportions of dextrose and levulose. It does not crystallize readily, and is produced in the boiling of acid fruit juices with cane sugar, as in the making of jellies, etc. Some authorities claim that invert sugar is sweeter than cane sugar. One author,[1] however, reports as the result of his experiments that invert sugar is five sixths as sweet as cane sugar. If this is the case, we should expect that more sugar would be required to sweeten canned fruit if added before cooking than if added afterwards. Fruit sugar, or levulose, is found in most fruits, and does not crystallize. Invert sugar is found abundantly in grapes, forming the yellowish

[1] Willard, Trans. Kan. Acad. Science, Vol. X, p. 25.

white granular masses in raisins. Levulose is of importance as a food for diabetic patients, as they utilize it more easily than any other form of carbohydrates.

Experiment 132. Test some dilute cranberry or currant juice with Fehling's solution for fruit sugar, then boil an equal quantity of the juice for 15 min. with a moderate amount of cane sugar, and test as above. Notice by the relative quantities of the precipitates whether the fruit acid has "inverted" some of the cane sugar.

HONEY

During the secretion of honey in the body of the bee, sucrose, which is the principal constituent of the nectar, is mostly changed to a mixture of dextrose and levulose. Wax, formic acid, and flavoring substances from the flowers are also present. It has been estimated that to obtain a kilogram of honey the bee must visit from 200,000 to 500,000 flowers. In some tropical countries certain varieties of flowers furnish a honey that is poisonous. Genuine honey should contain not more than 8% of sucrose, not less than 25% of water, not less than 0.25% of ash, and from 60 to 75% of reducing sugar. Whenever the dextrose is in excess of the levulose, it indicates adulteration with glucose. If ash is high, the sample is regarded with suspicion. Honeycomb consists of waxy substances which are probably incapable of digestion but not necessarily injurious.

The following analysis shows the average composition of genuine honey: [1] —

Sucrose (by Clerget)	.5% to 7.64%
Invert sugar	66.37% to 78.80%
Water	12.00% to 33.00%
Ash	.03% to .50%

[1] Canadian Dept. In. Rev., Bul. 47.

On account of the cost of honey the temptation to adulteration is very great. Cane sugar and glucose are the common adulterants. The expedient has also been tried of feeding bees upon glucose, but it is said that they do not thrive with this treatment. It was formerly a common practice to put up the so-called "strained honey" in jars, with a piece of the comb or a dead bee, as evidence of its genuineness. Artificial combs are also made, but have not found much favor with bee keepers. As honey is actually richer in sugar than the malt extracts recommended for invalids, and as this sugar is nearly all in a form to be readily assimilated, it is considered valuable as a supplement to the other carbohydrates in the diet.

Experiment 133. If honey contains dextrin, this is a good indication of adulteration with glucose. To test for dextrin add to the suspected sample 3 or 4 volumes of strong alcohol. In the presence of dextrin, quite a precipitate will appear, but in genuine honey only a slight cloudiness.[1]

Experiment 134. If honey contains any notable quantity of calcium sulfate, this is a pretty good indication of its adulteration with glucose. Test some diluted honey with ammonium hydroxid and ammonium oxalate for calcium.

Experiment 135. To test for the genuineness of beeswax, add to a portion some warm sulfuric acid. Wax will be blackened, while paraffin will be unchanged.

[1] Leach, *loc. cit.*, 3d ed., p. 641.

CHAPTER XVIII

ROOTS, LEAVES, STALKS, ETC., USED AS FOOD

In addition to the starch-bearing vegetable products discussed in Chapter XIII, there are a number of roots which are not particularly valuable, as sources of starch, but which give a variety to the food supply.

ROOTS

The carrot belongs to the botanical order *Umbelliferæ*, which includes many edible plants such as celery, parsnip, and parsley. Wild carrots have a very pungent odor and taste, but this has been modified by cultivation so as to be mild and agreeable. It is often necessary, however, to cultivate a taste for all the vegetables of this class. Carrots contain no true starch, but about 2.5% of pectose, gum, etc., 4.5% of sugar, 0.5% of albuminoids, and 89% of water. When carrots are boiled they lose over 90% of their nutrient material. This fact suggests that to retain any food value at all, carrots should be cooked in a soup or stew.

Parsnips have also been cultivated from the wild parsnip, The parsnip is somewhat more valuable as food than the carrot, as the former contains about 3.5% of starch, 5% of sugar, 3.7% of gum, pectose, etc., 1.5% of fat, 1.2% of albuminoids, and only 82% of water. It loses a large amount of nutrient material in boiling.

Turnips belong to the order of Cruciferæ. They contain pectose, 3%, instead of starch, and are very low in albuminoids and extractives. Turnips contain 92.8% of water; in fact they contain more water than milk. They are of little value, then, except for their flavor and to furnish variety to the bill of fare.

Beets are a more important food than any of those just mentioned, for the ordinary garden beet has been cultivated so that it contains from 10 to 15% of cane sugar, or about as much as the variety used for making sugar. Beets also contain 2.4% of pectose, and more cellulose than the other roots. The addition of vinegar to boiled beets helps to soften the cellulose, and, it is said, does not interfere with the digestion of other carbohydrates. After beets are boiled they contain only 3% of sugar.

LEAVES AND STALKS

The leaves and stalks of many plants are valuable both for food and for relishes. One reason for this is on account of the large amount of mineral salts that they contain. Some of these would be tough and woody if grown under the ordinary conditions, but if they are grown very rapidly, in an exceedingly rich soil, or if they are grown partly underground, or in the shade, they are quite tender. Though this class of foods often contains over 90% of water, yet their value should not be overlooked, for the gluten and starch which they contain are often in such a condition that they can be readily assimilated.

Prominent among foods of this class should be mentioned the cabbage, cauliflower, and kale. The cabbage contains 5.8% of carbohydrate, 1.8% of nitrogenous matter, and 1.3% of mineral matter, but when cooked the percentage

of water is increased to 97.4% and the other constituents decrease in like proportion. In general it may be said that the effect of cooking is to greatly diminish the amount of nutrients in this class of foods. The value of cabbage as a protection against scurvy, for those who are for a long time obliged to live on salted or canned meats, should not be overlooked.

Cabbage is sometimes packed in salt and preserved under the name of "sauerkraut." Here a kind of fermentation takes place and various organic acids are formed.

When cooked with potatoes to furnish the starch, and pork to furnish fat and a small amount of proteins, the deficiencies of cabbage are to some extent made up; really, however, the cabbage is but a flavoring for other food and adds to its bulk.

Many other succulent vegetables are used under the common name of "greens," and each has its agreeable flavor, and may be considered of value rather as a stimulant to the appetite than as a source of nutrient material. Among them may be mentioned: spinach, dandelion, endive, watercress, beet tops, narrow-leaved dock, and young poke sprouts. Lettuce, which also belongs to this class, contains a milky juice, having mild soporific properties, and considerable mineral salts, especially potassium nitrate. Asparagus, which is in much more common use than most of the foods mentioned, in the wild state is a seashore plant. It contains a peculiar crystallizable principle called "asparagin," $C_4H_8N_2O_3$, which has diuretic properties. When served with toast, the combination is an agreeable and useful food. Celery when in its wild state was known as "smallage." By intense cultivation much of the disagreeable odor has been removed, and it has found great favor. On the continent of Europe the root of

one variety is boiled, but in the United States the stalks, which are grown so that they are protected from too much light, are eaten raw for their agreeable flavor.

Rhubarb (*Rheum raphonticum*), under the name of "pie plant," is a useful garden production. The leaf stalks when cooked with sugar are used, on account of their flavor and the acid which they contain. As the plant is a slight laxative, it may be useful in cases of constipation. Rhubarb contains a peculiar flavoring substance and considerable acid potassium oxalate.

Experiment 136. Express the juice from several stalks of rhubarb and filter it. Add to some of the clear juice a little solution of calcium chlorid, and notice the precipitate of calcium oxalate produced.

OTHER VEGETABLE FOODS

The onion, leek, and garlic are chiefly prized for their pungent volatile oil, rich in sulfur, which makes them useful in flavoring other food.

The tomato, although not properly belonging to this class, may be here discussed. It is a native of South America, and was introduced into Europe in 1596. It has been grown and used in enormous quantities in the United States since about 1850. The raw tomato contains 91.9% of water, 1.3% of nitrogenous matter, 5% of carbohydrates, and .7% of mineral matter, and therefore is not very valuable as a nutrient, but is properly classed as a relish. Tomatoes owe their acidity mostly to the presence of malic acid. When made into "catsup" or "paste," the product is sometimes adulterated, and various preservatives are also used.

ALGÆ, LICHENS, AND FUNGI USED AS FOOD

The most important of the algæ is the Irish or Carrageen moss. When dried, as usually prepared for market, it contains 9.4% of nitrogenous matter and 55.4% of a vegetable mucilage. Its value as a nutrient is not fully understood.

Iceland moss is darker in color than Irish moss and contains 8.7% of proteins and 70% of a lichen starch, which is unaffected by digestion, and probably does not form glycogen. It has not been proved that it has any value as food.

The edible fungi are popularly classed as mushrooms and the poisonous ones as toadstools, but this is not a scientific classification. Mushrooms are employed not only for flavoring, but also as food. They are grown in large quantities in Europe in caves and cellars, in an exceedingly rich soil. They contain from 1.19 to 6.1% of proteins, and from 1.2 to 6% of carbohydrates, but starch is not present among the carbohydrates. Although the analysis shows considerable nitrogen, much of this is in such a combination that it is not available for nutrition. It is said that mushrooms are not easily digested, on account of the large amount of cellulose which they contain. Some authorities claim that their use as a nutritious food should be encouraged, while others believe them to be simply a rather expensive flavoring material. The varieties known as truffles and morels are quite popular in England and on the Continent.

Unfortunately several varieties of mushrooms are extremely poisonous. In some cases the symptoms of the poisoning do not appear till after more than twenty-four hours. The poisonous substance is an alkaloid, a gluco-

side, or a toxalbumin, and is of different composition in the different varieties.[1] As the taste for mushrooms is being cultivated, a larger number of persons are becoming acquainted with the characteristics of edible mushrooms, and in some countries special pains is taken to educate the common people to recognize the non-poisonous varieties. There seems to be no safe rule, however, by which we can distinguish between the poisonous and edible varieties, and it is hazardous for persons not well acquainted with fungi to attempt to do this.[2]

[1] See U. S. Dept. Agric., Div. Microscopy, Food Products, 1893–1894.
[2] "Source, Chemistry and Use of Food Products," Bailey, p. 296.

CHAPTER XIX

THE COMPOSITION AND FOOD VALUE OF FRUITS

The term "fruit," in the restricted sense, includes the pulpy substance inclosing the seeds of various plants, and especially those which are edible in the raw state.

Fruits are essential to the distribution of plants, and have been utilized by man as food, as an agreeable luxury, and an aid to digestion. In general it may be stated that the seed is surrounded by some sweet, or edible envelope, to attract birds, insects, and quadrupeds, and in this way insure the scattering of the seed over a wider extent of territory.

The seed proper is surrounded by a fleshy portion known as the pericarp. A green fruit does not differ very much from the leaf in composition, but in the process of ripening, under the influence of sunlight, the fruit undergoes a remarkable change in color, texture, composition, and flavor. During the change it ceases to act on air like a leaf, but begins to absorb oxygen, and give out carbon dioxid gas.

As the process of ripening goes on, both the invert sugar and the sucrose increase and the starch and free acid decrease. After the disappearance of the starch the sucrose disappears quite rapidly on account of its change to invert sugar. Malic acid appears to decrease, but this phenomenon is largely due to the fact that it is formed in the early life history of the fruit, and is diluted by its growth.

These changes are very well illustrated by the examination of the analyses of Ben Davis apples, which were made at different stages of their growth.[1]

Date of Analyses	Total Solids	Acid as Malic	Starch	Sucrose	Invert Sugar
June 16 . . .	13.63	1.64	2.23	.49	2.35
June 30 . . .	13.37	1.27	3.03	.67	3.04
July 13 . . .	13.58	——	3.72	1.21	5.09
July 28 . . .	15.71	.89	3.67	1.13	4.52
Aug. 18 . . .	14.92	.78	3.16	1.46	4.36
Sept. 24 . . .	15.05	.52	2.40	2.59	4.83
Oct. 15 . . .	14.86	.52	1.46	3.13	5.30
Oct. 23 . . .	14.82	——	.94	3.92	5.53
Oct. 30 . . .	14.68	.43	.38	3.87	5.84
Nov. 5 . . .	15.73	.41	——	3.71	5.83

It is supposed, while ripening, that the insoluble pectose changes into pectin and secondary substances of a gelatinous nature. The tannin that made the fruit astringent also disappears. As the fruit becomes overripe, some of the sugar and acid is oxidized or otherwise changed, and the fruit loses its agreeable flavor. On cold storage this latter change is deferred by the low temperature, but a very short exposure to air, at ordinary temperature, causes the fruit not only to appear overripe but to decay quickly. During the process of decay, which is assisted by fermentation, carbon dioxid and alcohol are at first formed from the sugar, and later the alcohol is oxidized to acetic acid, and finally in the decayed fruit the seed is set free, ready to start a new plant.

Fruits owe their agreeable taste to the right proportion of the constituents mentioned in the table on p. 265, and

[1] Bigelow, Gore, and Howard, U. S. Dept. Agric., Bu. Chem., Bul. 94, p. 46.

to the compound ethers and essential oils that may be present. These flavoring substances are many of them present in such small quantity that they are not mentioned in the analysis.

The composition of some of the most important fruits, as purchased, and including the refuse, is given by Atwater and Bryant,[1] as follows: —

FRUITS

	Refuse	Water	Protein	Fat	Total Carbohydrates	Crude Fiber	Ash
Apples	25.0	63.3	.3	.3	10.8	—	.3
Blackberries	—	86.3	1.3	1.0	10.9	2.5	.5
Cherries	—	76.8	.9	.8	15.9	—	.6
Cranberries	—	88.9	.4	.6	9.9	1.5	.2
Currants	—	85.0	1.5	—	12.8	—	.7
Figs, fresh	—	79.1	1.5	—	18.8	—	.6
Grapes	25.0	58.0	1.0	1.2	14.4	—	.4
Muskmelon	50.0	44.8	.3	—	4.6	—	.3
Oranges	27.0	27.0	.6	.1	8.5	—	.4
Pears	10.0	76.0	.5	.4	12.7	—	.4
Plums	50.0	74.5	.9	—	19.1	—	.5
Raspberries	—	85.8	1.0	—	12.6	2.9	.6
Strawberries	22.	85.9	.9	.6	7.0	—	.6
Watermelon[2]	59.4	92.4	.4	.2	6.7	—	.3

Some fruits that seem to "melt in the mouth" really do contain considerable soluble matter. It is a well-known fact that sugar disguises acids, and that an agreeable taste in preserved fruits is often due to a judicious mixture of the acid and the sweet. The most important nutritive material in fruits is in the carbohydrate group: of course there are some special fruits like the olive and the avocado which contain large quantities of fats. Al-

[1] U. S. Dept. Agric., Office of Exp. Sta., Bul. 28. [2] Edible portion.

though starch is found at certain stages of growth, sugar is the most abundant of the carbohydrates. This is usually invert sugar, but apricots, pineapples, and apples contain also cane sugar. This fact has an important bearing on the dietetic use of fruits, as invert sugar is, in some diseases, as diabetes, more easily assimilated than cane sugar.[1]

The pectous bodies referred to above are not very well understood, but are regarded as resulting from the combination of several simpler carbohydrates.[2] The insoluble galacto-araban is supposed to give the property of hardness to unripe fruits and vegetables, and is the basis for the making of jelly. The statement has been made that as the fruit becomes riper the pectose is changed by the action of acids into pectin, a vegetable jelly, which causes the juice after boiling to gelatinize when cooled. This may be noticed in the juice that exudes in the baking of apples. It is supposed that by too long boiling these pectous compounds are concentrated into a more soluble modification, and, if this is true, it may explain the fact that sometimes fruit juices that have been boiled for a long time become thick and viscid, but do not form a true jelly. A partially ripe fruit is better adapted to making a jelly than one that is fully ripe.

From what has been said it is evident that pectin bodies are substances in a "colloid" condition very widely distributed in plant tissues. They occur both in soluble and insoluble forms. In the study of these bodies "the most important problem appears to be the quantitative determination of the pectin bodies occurring in a given tissue, because such a method could be used to determine the

[1] See also, "Source, Chemistry and Use of Food Products," Bailey.
[2] Univ. Ill. Bul., Vol. 9, No. 36.

function of the material in plants: whether, for example, it is a reserve material, a by-product, is used for structural purposes, or has all three functions or two of them; whether the nature of the pectin body changes with the growth of the tissue, or possesses a practically constant composition; whether the pectin bodies obtained from different sources are identical, are mixtures of the same substances (such as araban and galactan) in varying proportions, or are inherently different." [1]

Experiment 137. To the filtered juice of a ripe apple add an equal bulk of alcohol, and a gelatinous mass consisting largely of pectin will be precipitated. Dry the product, and it will be found that the powder thus obtained is soluble in cold water.

Experiment 138. Stew a handful of cranberries, filter the juice, add a little sugar, and allow it to stand until cold, when an abundant jelly is obtained.

Experiment 139. Test some green fruit, a persimmon or banana, for tannin by extracting the juice, filtering, and adding a small quantity of ferric chlorid. The production of a black, or greenish black, color indicates tannin.

FRUIT ACIDS

The acidity of fruits is due to the presence of the free acids, malic, citric, tartaric, or racemic, or their acid salts. They not only have an agreeable acid taste, and serve as appetizers, but when oxidized in the body are converted into the corresponding carbonates, and these help to render the blood more alkaline and the urine less acid.

Malic acid ($H_2C_4H_4O_5$) is found in many acid fruits, as cherries, apples, raspberries, gooseberries, rhubarb, unripe mountain ash berries, etc.

[1] Bigelow, Gore, and Howard, U. S. Dept. Agric., Bu. Chem., Bul. 94, p. 86.

Experiment 140. Add to a solution of malic acid, calcium chlorid, ammonium chlorid, and ammonium hydroxid in excess. There should be no precipitate, but upon adding to this 3 volumes of alcohol, calcium malate ($CaC_4H_4O_5$, 3 H_2O) should separate out as a precipitate.

Experiment 141. Since the acid potassium malate exists in the stalks of the common rhubarb, the juice that is expressed from this may be filtered and tested for malic acid by the test described in Experiment 140.

Citric acid, $H_3C_6H_5O_7$, occurs in the juice of lemons, currants, unripe tomatoes, gooseberries, etc. It is made on a large scale from lime or lemon juice, by saturating the juice with chalk; the precipitate of calcium citrate is decomposed by an equivalent quantity of sulfuric acid and filtered from the calcium sulfate. Evaporate the filtrate and crystallize out most of the calcium sulfate, and from the mother liquor allow the citric acid to crystallize.

Experiment 142. Make citric acid from the juice of at least two lemons, as above described.

Experiment 143. Add a moderate quantity of calcium chlorid to a concentrated solution of citric acid, and then add sodium hydroxid till the solution is nearly neutral. Calcium citrate, $Ca_3(C_6H_5O_7)_2$, will be formed.

Experiment 144. Try the above test with a concentrated and filtered sample of lemon juice, and note the formation of the precipitate of calcium citrate.

Tartaric acid ($H_2C_4H_4O_6$) is found in many fruits, particularly ripe grapes, as acid potassium tartrate ($KHC_4H_4O_6$). When the "must" ferments, the "cream of tartar" precipitates as the alcohol increases, and this precipitate is known in the market by the name of "argol," or crude tartar.

It is frequently much contaminated with calcium sulfate, which is used in "plastering" the wine. To make tartaric acid from this, the solution of the argols is treated with milk of lime to form the calcium tartrate, and the latter salt is suspended in water and treated with an equivalent of sulfuric acid, the calcium sulfate so formed is filtered off, and the tartaric acid is obtained in crystals by concentration of the filtrate.

Experiment 145. Add to a concentrated solution of tartaric acid a concentrated solution of potassium chlorid, when a precipitate of acid potassium tartrate will be formed on shaking and allowing to stand at ordinary temperature. The test is more delicate if the solution is nearly neutralized with sodium carbonate before the potassium chlorid is added.

Experiment 146. Make a similar experiment with filtered grape juice, which may conveniently be obtained from canned grapes. A more delicate test is made by adding to 100 cc. of the fruit juice a few drops of strong acetic acid, a few drops of a concentrated potassium acetate solution, and 15 g. of pure, finely ground potassium chlorid; dissolve the latter salt by shaking and add 20% of 95% alcohol. Stir and shake vigorously to assist in the crystallization of the acid potassium tartrate.

COOKING FRUITS

Cooking improves many fruits by softening the cellulose and converting the gums and allied bodies into a gelatinous form. Sucrose is inverted and pectin bodies converted into soluble forms. If there is starch remaining, this is made more digestible by cooking. There are many fruits that in the raw state are not suitable to use as food for persons with dyspeptic tendencies. They are, however, very satisfactory and useful when suitably cooked. Apples, pears, quinces, and cranberries belong

to this class. It should also be noted that a jelly made from a fruit juice is usually much more acceptable to an invalid and less irritating in its action than the raw fruit or the jam. This is especially true of raspberries, blackberries, and currants, on account of the numerous fine seeds that are present in the jam.

Cultivation has changed the character of many fruits, and has much improved their flavor, so that many luscious fruits have been developed from disagreeable, or, to say the least, very medium stock.

JAMS AND JELLIES AND THEIR ADULTERATION

Although a few years ago preserved fruit products were all prepared by the housewife, at the present time much of this work is turned over to the manufacturer, and he has the opportunity and often the incentive to falsify the material, and to give it a fictitious value in color, odor, sweetness, flavor, and preservative qualities. Much work has been done on this subject by the United States Department of Agriculture and at State Experiment Stations. The presence in these products of anything in addition to the fruit and cane sugar should be regarded as an adulteration. If they are made up with foreign materials they should, in the interest of the purchaser, at least be labeled "compound."

The substitute for jam and jelly, which is sold at say 10¢ per half-pound jar, is often made of apple juice or "trimmings" from canning factories, and glucose, colored with coal-tar dyes to imitate any natural product, as strawberry, currant, etc., and occasionally flavored with an artificial fruit essence.

As it is difficult to secure sufficient stiffness in an apple-

jelly stock with glucose, a little citric, tartaric, or phosphoric acid is added to cause the mass to gelatinize.[1]

Foreign seeds, like that of the clover, are sometimes used. Although a sample of jam may contain the seeds of the genuine fruit, and so appear to be genuine, yet the fruit may be first used to make a high grade of jelly, and the residue may be afterwards worked up into a cheap jam.

Experiment 147. The test for a coal tar dye in jelly may be made as follows: Strips of a fine woolen cloth, such as "nun's veiling," are boiled and then thoroughly washed. One of these strips is then boiled for about 15 min. in a diluted, filtered solution of the jam or jelly, to which a little potassium bisulfate has been added. The wool is then taken out and boiled with water containing a very little soap, and if it has been colored at all with the dye it is digested in another beaker with dilute ammonia, which will dissolve the colors fixed in the acid bath. Take out the fabric, slightly acidify the solution, and boil with a new piece of the fabric. This second dyeing will fix the coal-tar colors, on the goods but will not fix the natural fruit colors. There are a few rather uncommon coloring matters, made by chemical methods of manufacture from vegetable substances like cudbear and archil, which are not to be distinguished from aniline dyes by any method of dyeing.[2]

Experiment 148. To detect starch in jelly, heat an aqueous solution of the sample nearly to the boiling point and decolorize by the addition of several cubic centimeters of dilute sulfuric acid and afterwards a small quantity of potassium permanganate. Cool the solution, filter if necessary, and test for starch by the iodine reagent as usual. Very little starch is normally present in apple juice, but if the jelly is made from apple parings and trimmings a little starch is frequently present.[3]

[1] Leach, "Food Inspection and Analysis," 3d ed., p. 934.
[2] Winton, *J. Am. Chem. Soc.*, 22, 1900, p. 582.
[3] U. S. Dept. Agric., Bu. Chem., Bul. 65.

FRUIT SIRUPS; FLAVORING EXTRACTS

The fruit sirups upon the market may be made from genuine fruit, sterilized by heating, and put up practically like canned fruit, or they may be entirely artificial, like some of the jellies just mentioned.

VANILLA EXTRACT

Among the flavoring extracts, that of vanilla and lemon are most extensively used. Practically, only a small proportion of the vanilla extract on the market is made wholly from the vanilla bean, as this is very expensive. Most of the agreeable flavor of vanilla extract is due to the presence of a body called vanillin, $C_8H_8O_3$. Many of the cheaper so-called vanilla extracts on the market are made by the use of the Tonka bean, which contains the active principal coumarin, $C_9H_6O_2$. Some manufacturers claim that the quality of the extract is improved rather than otherwise by the use of the Tonka bean.

Much of the ordinary " compound " vanilla extract is made by the use of the artificial vanillin, and artificial coumarin, with some coloring matter and sugar, added to a weak alcoholic tincture of the Tonka bean.[1]

Experiment 149. Place some extract of vanilla in an evaporating dish on a water bath and evaporate off half of the liquid. Add cold water to make up to the original volume. By this treatment the alcohol will be driven off, and in the watery solution that is left the substances in true vanilla are nearly insoluble, so the liquid will be cloudy and of a dirty brownish color. The artificial extract, on the other hand, will be bright and clear.

[1] Lab. Inl. Rev. Dept. Can., Buls. 89 and 114.

Experiment 150. In a test tube add a little of a solution of sugar of lead to some of the extract of vanilla. The true vanilla extract will give an abundant yellowish brown precipitate and a pale yellowish liquid. Upon the artificial extract the lead solution has but little effect, and there is only a slight discoloration. Another test is to notice the character and color of the foam produced on shaking some of the artificial vanilla extract. The bubbles will retain their bright caramel color till the last ones have disappeared, while, if the extract is genuine, the bubbles are much lighter in color.

LEMON EXTRACT

Extract of lemon should contain, according to the U. S. Pharmacopœia, 5% of oil of lemon, and to keep this in solution will require alcohol of 80% strength by volume. Much of the extract of lemon on the market contains only a trace of the oil, and less than 40% of alcohol. A sample of alcohol so dilute as this will dissolve only a very small quantity of the oil, although there may be enough to give the extract a slight taste and odor. Such extracts are usually colored yellow by the use of coal-tar dyes.[1]

Experiment 151. To 50 cc. of water add 10 cc. of the extract of lemon to be tested. If the solution becomes milky, on account of the precipitation of the oil of lemon, it is of good quality, but if it remains clear only traces of the oil are present.

ARTIFICIAL FRUIT ESSENCES

Most of the artificial fruit essences, such as that of strawberry, banana, raspberry, apple, and pineapple, are made by ingeniously combining various compound ethers, organic acids, and essential oils. These are usually colored with aniline colors, and may be sweetened by the use of glucose or saccharin.[1]

[1] U. S. Dept. Agric., Bu. Chem., Bul. 65.

CHAPTER XX

EDIBLE FATS AND OILS

The fats used in the manufacture of soap have already been discussed, but the importance of certain fats and oils in food products warrants some further attention to them in this connection. The facility with which a fat saponifies (see p. 129) is of great importance in the process of digestion. The fats are insoluble in water, but readily soluble in ether, chloroform, oil of turpentine, and similar solvents.

Like starch and sugar, the fats do not directly form muscular tissue, but they have $2\frac{1}{4}$ times the power to maintain the heat and activity of the body that the carbohydrates possess. There seems to be little difference whether the fat comes from a vegetable or an animal source.

The amount of fat existing in some food products is as follows: —

From vegetable sources —

	Per Cent		Per Cent
Almonds	54.0	Sunflower seed	20.5
Peanuts	41.6	Oatmeal	6.0
Olives (pulp)	56.4	Indian corn (white)	4.2
Cacao	44.0	Wheat bran	4.0
Cocoanut	68.7	Peas	2.5
Cotton seed	20.1	Wheat flour	1.0

From animal sources —

	Per Cent		Per Cent
Butter	84.4	Poultry	16.3
Bacon	65.0	Mackerel	13.0
Mutton chop	35.0	Eggs (whole)	11.0
Cheese	30.0	Cow's milk	4.0

When fat is deposited in the body beneath the skin, it keeps in the warmth of the body. The fat, wherever deposited, may be reabsorbed into the blood, and thus keep up the animal heat for a long period even when food is not taken. This is the case with animals which hibernate for several months.

The demand for some of the oils has been constantly increasing. Previous to 1870 it was quite a problem to the cotton planters how they should dispose of their **cotton seed**, while to-day the oil extracted from it finds numerous uses. A large quantity is exported to Europe, where it is used in the manufacture of soaps and butterine, and occasionally as an adulterant for olive oil. Cottonseed oil is used in the United States in canning factories in the preservation of fish, in the manufacture of "cottolene," butterine, and soap, and for the preparation of salad dressing. The cottonseed-oil product of a single year was 93,325,729 gal. and only 53% of the possible product was produced.

The oil of the **cocoanut** is also exceedingly valuable, both for cooking and in the manufacture of soap. It is imported from various tropical countries, especially Ceylon and the East Indies. Unfortunately, the oil soon becomes rancid, and therefore it is more extensively used for food in the countries where it can be freshly obtained than elsewhere.

LARD

The " rendered " fat of the hog has the general name of lard, but there are several different grades made at the packing-house. The lowest grade, known as " steam-rendered " lard, or " prime steam lard," is extracted from the stock by admitting steam to the tank under a pressure of 40 to 50 lb. The object of cooking lard or suet material is to break the membranous cells, thus allowing the fat to escape, and to heat the small quantity of the nitrogenous portion that may remain in the finished product so that it will not readily decompose.

A " refined lard " is sometimes made from the " prime steam lard " by heating it in a tank to 170° F. and blowing in air for some time to remove moisture. It is then bleached at a temperature of 150° to 165° F., by agitation with Fuller's earth, and filtered through a filter press. The final operation in the manufacture consists of cooling rapidly, either by agitating in a tank surrounded by cold water, or by running the lard on to a large roll, which is filled with ice-cold brine, and which slowly revolves.

Kettle " rendered " lard is that which is made in kettles heated externally, and corresponds to ordinary household lard. The best grade of " leaf lard " belongs to this class. The material, which has been thoroughly washed, is heated at as low a temperature as possible to secure the result, in steam-jacketed kettles, and when fully rendered is drawn off into a settling tank, before being filled into packages for shipping. The " scrap " remains in the bottom of the rendering kettle, and is worked over again.

The method of making " neutral lard," which is made from leaf lard principally, is described under oleomargarine (Chapter XXIII). As it is not fully heated, its keeping

qualities are not good, and it must be kept in cold storage.

Lards are sometimes "stiffened" so that they will not melt so readily in a warm climate, and if this is done by the addition of lard stearin it is not considered an adulteration, but the use of the oleostearin from beef should be considered an adulteration.

"COMPOUND LARD," "COTTOLENE," "COTTOSUET"

There are a number of products on the market which do not pretend to be lard, but are made to use for the same purposes, and can be sold at a lower price. Different mixtures of fats are used for the trade of different countries, and for summer and winter trade. The chief materials used are: cottonseed oil, oleostearin, tallow, and sometimes lard. These materials are each carefully bleached before being mixed.

THE COMPOSITION AND FOOD VALUE OF NUTS

Within the last few years many nut preparations have appeared on the market, so that their use as food should be no longer ignored. Nuts have a much higher nutritive value than fruits, as can be readily seen from their composition.[1]

Nuts as Purchased	Refuse	Water	Protein	Fat	Total Carbohydrates	Ash
Almonds . .	45.0	2.7	11.5	30.2	9.5	1.1
Chestnuts .	16.0	37.8	5.2	4.5	35.4	1.1
Cocoanuts .	48.8	7.2	2.9	25.9	14.3	.9
Hickory nuts	62.2	1.4	5.8	25.5	4.3	.8
Pecans . .	53.2	1.4	5.2	33.3	6.2	.7
Peanuts . .	24.5	6.9	19.5	29.1	18.5	1.5

[1] U. S. Dept. Agric., Office Exp. Sta., Bul. 28.

Since they contain a large amount of fat, various nut preparations are used as substitutes for butter. On account of the fact that nuts are not readily digested in the stomach, the attempt has been made, and with considerable success, to improve the product, by crushing and removing the excess of oil and cellulose.

Chestnuts,[1] which are used very extensively as food by the peasants of southern Europe, have been mentioned under the starchy foods.

In the **almond**-producing countries the nut is eaten both green and dry. When the skin has been softened by soaking for some time in warm water, it may be removed and the nuts are said to be " blanched."

It is interesting to note that there are two kinds of almonds, the sweet and the bitter, both of which contain a peculiar ferment called " emulsin." The bitter almond contains, in addition to this, an interesting " glucoside " known as amygdalin, $C_{20}H_{27}NO_{11} + 3\ H_2O$. This, in the presence of water, is broken up by the emulsion into glucose, benzoic aldehyde, and hydrocyanic acid, HCN. It is on account of the formation of this latter compound that bitter almonds are poisonous. Amygdalin is also obtained from the seeds of plums, peaches, cherries, apples, etc.

The **cocoanut** is probably the most important of any staple nut products. As the edible part or meat contains about 50 % of oil, the abundance of nutrient material can be readily appreciated. Each tree yields from 80 to 100 nuts a year, and will continue to bear for at least two generations. The importance of the oil in various industries, such as that of soap and candle making, should not be overlooked.

[1] " Source, Chemistry and Use of Food Products," Bailey, p. 333.

The **peanut**, although not properly a nut, as it belongs to the leguminous family, since the edible portion contains about 38% of oil, may properly be considered here. As it contains 25% of albuminoids, and considerable starch, it very deservedly is coming into more general use both as a food for man and for cattle. Three hundred million pounds of peanuts are grown annually for use in the United States. The principal peanut-producing states are Virginia and North Carolina. As sweet almonds and peanuts resemble meat in their high protein and fat content, they may be used to a certain extent to take the place of meat.

Experiment 152. To show the relative amount of stearin in different oils, place test tubes containing samples of cottonseed oil, olive oil, corn oil, peanut oil, etc., in a beaker containing melting ice. After some time observe the precipitate of stearin in each sample.

CHAPTER XXI

NITROGENOUS FOODS

In Chapter XII it is stated that foods are divided into two general classes, carbohydrate and nitrogenous, and that the carbohydrate foods contain sugars, starches, dextrins, and fats, and also that there are many foods that contain both classes of nutritive materials. The relation between these different foods may be seen by comparing the composition of the cereals and the leguminous foods.

If, however, we wish to make use of a concentrated nitrogenous food, it is possible to utilize the system of some animal that subsists on vegetable food, and so we use as nitrogenous foods, beef, mutton, lean pork, fish, oysters, poultry, game, milk and its products, and eggs. Of all these, beef may be regarded as the most typical nitrogenous food, and it is, no doubt, the most valuable meat for all purposes.

Animal foods leave comparatively little residue, as they are practically completely digested; they form, then, a concentrated food. Not only are the animal foods of agreeable flavor, but they contain mineral salts, which are of great value in the nutrition of the body.

"Since, in some way as yet unknown to us, nitrogen is essential to living matter, such substances as contain this element in an available form are of first importance. Some, as albumen, are so closely allied to human protoplasm that they probably need only to be dissolved to be at

once assimilated. Others, as gluten and similar vegetable products, undergo a still greater change; while still others, as gelatin, have a less profound but marked effect in protecting the tissues from waste. Still other nitrogenous substances, as the alkaloids, seem to affect the nerve tissue for good or ill. The enzymes, ' ferments ' in part, of the older nomenclature, are also highly nitrogenous substances, present in some form in nearly all the foodstuffs of natural origin. The nearer the composition of the food approaches to the protoplasmic protein, presumably the greater its food value, since each cleavage, each hydrolysis, each step in the breaking down of the highly complex molecule, consisting of hundreds of atoms, is supposed to liberate stored energy. Therefore it is not a matter of indifference in what form this essential is taken." [1]

CLASSIFICATION OF NITROGENOUS SUBSTANCES

The following is a convenient classification of nitrogenous bodies that occur in food.[2]

I. **Proteins.** These bodies contain nitrogen, oxygen, hydrogen, carbon, and sulfur, and are capable of being converted, in the body, into proteoses and peptones. They may be present in either animal or vegetable food. Under this general head the following divisions are made: —

1. Albumins, which occur in eggs, milk, cereals, etc.

2. Globulins, which occur in serum, in blood, as myosin in meat, as vitellin in egg yolk, and as vegetable vitellin in cereals and in peas, beans, etc.

3. Albuminates, occurring in casein of milk, in peas and beans, and in almonds.

[1] Richards and Woodman, "Air, Water, and Food," p. 142.

[2] Leach, "Food Inspection and Analysis," p. 40.

4. Proteoses, which occur in sour milk, ripened cheese, and wheat flour.

5. Peptones, which are found in meat.

6. Insoluble proteins, such as fibrin and myosin, in animal foods and gluten in wheat.

II. Albuminoids. These are much like the proteins, and may be divided into —

1. Collagen, which composes the fibers of connective tissues.

2. Gelatin, which is made by boiling bones.

3. Mucin, which is found in meat and also in mucus.

4. Nuclein, which occurs in the nuclei of cells in the egg yolk and milk.

5. Chondrin, a substance that may be obtained from cartilage by long boiling.

6. Elastin, which forms the elastic fibers of connective tissue.

III. Amides, amido-acids, and allied products include cholin ($C_3H_{15}NO_3$), betain ($C_5H_{11}NO_2$), and asparagin ($C_4H_8N_2O_3$).

IV. Alkaloidal substances, such as those occurring in the beverages, tea, coffee, cocoa, and kola.

V. Nitrogen, as nitrates.

VI. Nitrogen, as ammonia.

VII. Lecithin ($C_{44}H_{90}NPO_9$), which is found in egg yolk, cereals, and legumes.

" The function of the albuminous substances is probably threefold, as they contribute to the formation and repair of the tissues and fluids of the body, and in a special manner of the nitrogenous tissues; they regulate the absorption and utilization of oxygen, and so play an important part in the chemistry of nutrition; and under special conditions they may also contribute to the forma-

tion of fat, and to the development of muscular and nervous energy, and to the production of heat." [1]

The structure of lean meat may be compared to bundles of tubes or fibers filled with rich nitrogenous juices. These fibers are soft and tender in the young animal, but with age the muscles become toughened and more firmly bound together. This muscular tissue is divided into two classes: the voluntary, or striated muscles, like those of the shoulder; and the involuntary, or non-striated muscles, like those of the heart. The latter are not considered so valuable for food. The substance of the connective tissue consists chiefly of the albuminoids, elastin, and collagen, the latter being a substance which is changed by boiling with water or treatment with acids into gelatin. The proteins of the meat juice consist chiefly of the globulin myosin, muscle albumen, and muscle pigment.

In the living muscle, while there are no peptones, the ferment pepsin is present, and after death, by the action of the pepsin in the presence of lactic acid, a portion of the normal protein of the muscle seems to undergo a kind of digestion, so that in the meat traces of both peptones and proteoses are found. Ordinarily these latter bodies are the result of some digestive action on higher proteins. We have also present in the meat, creatin, xanthin, etc., which are known as flesh bases. It is evident that the nitrogenous bodies constitute the bulk of lean meat, while the carbohydrates are almost entirely lacking. It should be noted that the different "cuts" of meat have entirely different food values. It is not possible by a chemical analysis alone to distinguish between the meat from different animals.

Since myosin has the property of clotting after death,

[1] I. B. Yeo, "Food in Health and Disease," p. 13.

the meat undergoes the process of muscle stiffening or *rigor mortis*. If the meat is allowed to stand until this condition has passed off, on account of the resolution of a part of the myosin, and the partial digestion from the pepsin present, it becomes tender again. This process should not be allowed to go too far, or the meat will become " high " and have a disagreeable odor and flavor.

The character of the extractives very much modifies the flavor of the meat, and if these extractives are removed by prolonged boiling or digestion with water, the meat has very little taste. The following analyses show the proportion of the important ingredients in one kind of meat: —

EFFECT OF COOKING

Lean Beef[1]		Raw Beef[2]	Roasted Beef[2]
Protein	18.36	Water	70.88	55.39
Gelatin (Collagen?)	1.64	Nitrogenous matter	22.51	34.23
Fat	.90	Fat	4.52	8.21
Extractives	1.90	Extractives	0.86	0.72
Ash	1.30	Min'l salts	1.23	1.45
Water	75.90			

THE USE OF ANIMAL FOOD

According to Mulhall the quantity of animal food used per year per capita is as follows in the different countries:

	Pounds		Pounds
United States	120	Scandinavia	67
Great Britain	105	Austria	64
France	74	Spain	49
Germany	69	Russia	48
Belgium and Holland	69	Italy	43

[1] Bischoff & Voit. [2] König.

COOKING OF MEAT

The general object of cooking food has already been discussed (p. 165). In the case of meat, high temperature not only softens the fibers and makes the product more agreeable to the taste, but it is only in this way that we can be sure that pathogenic bacteria and parasites are destroyed.

The following processes of cooking may be applied to meat: boiling, roasting, broiling, baking, stewing, frying.

In the cooking of meat it is essential to know the object desired in the process. If we want an extract, the meat should be placed in cold water and kept at a temperature below 160° F., for several hours, with the addition perhaps of a little salt. This is the method for extracting the nutritive material for making soup. Recent experiments, however, show that there is not as much difference in the composition of meats immersed in cold water and then cooked at 85° C., and those plunged at once in boiling water and cooked at 85° C., as was formerly supposed. If, on the other hand, we desire to retain the rich juices in the meat, it must be heated as quickly as possible, especially on the outside, so as to prevent the escape of these juices with their accompanying flavors.[1] This is done most practically by broiling the meat, and to some extent by baking or roasting. The process of frying meat is very unsatisfactory and affords a product that is tough and unwholesome.

The greater part of the proteins, both animal and vegetable, are coagulated at about 170° F. Fats are not as much affected by heat as carbohydrates and proteins, but when they are heated to a high temperature, they are

[1] Grindley, U. S. Dept. Agric., Office Exp. Sta., Bul. 162.

liable to become partially decomposed. It is reasonable, then, to suggest that if meat is boiled, in order to retain the juices which it contains, the meat should be plunged into boiling water for a few minutes, thereby sealing up the juices within the fibers, then lowering the temperature for the thorough cooking of the meat. If a small quantity of water is used, less of the soluble material will be extracted. The average loss in weight when meat is cooked in hot water is about 34 %.[1]

In the process of roasting, especially when the meat is "basted," the same method for sealing up the tubes is used, so that the juices may be retained. This is still better accomplished in broiling or grilling, because the heat that is at first applied is more intense and later the meat has an opportunity to cook toward the interior, so that the flavor is superior and the agreeable extractives are largely retained.

In stewing or preparing a "pot roast," as the heat is low and long continued, and as the juices that happen to be extracted are all served with the meat, the process is very satisfactory. If the temperature in stewing is not allowed to rise about 180° F., the meat will fall apart readily, and the proteins will not be coagulated, hardened, or rendered indigestible. It is an interesting fact that while vegetable foods take up water when they are boiled, animal foods actually lose water. According to some recent investigations,[1] the average amount of water in 14 samples of uncooked meats was 70.08 %, while in the 31 samples cooked in hot water it was only 57.50 %.

[1] *Loc. cit.*

BEEF EXTRACTS

There has been much discussion as to the nutritive value of beef extracts, and the conclusion seems to be that the commercial extracts are not as valuable as a simple beef extract made by slightly broiling the beef and then squeezing out the juice. It is a mistake to suppose that 1 lb. of beef extract contains the soluble constituents of 20 to 30 lb. of lean beef, and that, as Baron Liebig once taught, it is equal in nutritive value to this amount of beef. This extract lacks many of the most nutritious constituents, especially the proteins, and probably acts more as a stimulant and a substance to rouse the appetite for other foods, than as a true food.[1] There are also preparations on the market which consist of extract of beef, to which some of the meat fiber has been added. They are shown by analysis to contain some protein. "Beef juices," which should be made by expression of the juice from the raw or slightly heated meat, contain considerable protein and are valuable nutrients.

Referring to the fluid meat preparations, Thompson[2] says: "Usually they are tired of soon, and do not support life long, for, beyond the means employed of condensation of food by evaporation of water and compression, it is not possible to 'concentrate' nourishment very much. Making food assimilable and more useful is another matter from concentrating it in the sense that it can be made to support an able-bodied man and supply him with energy for a day's work, for example, of mountain climbing."

The various kinds of meat do not differ in their composition as much as might be supposed. Some contain

[1] Church, "Food," p. 183.
[2] "Practical Dietetics," p. 118.

more water, some contain more fat. The fats, it will be remembered, belong to the same class as the carbohydrates; that is, they are "work and heat producers," and not "tissue formers" like the nitrogenous foods. Comparative analyses show that when fat is deposited in a muscle, it replaces water, and not protein, so the gain in nutritive matter is not attained by the loss of nitrogenous materials. Lean beef may contain 19% of nitrogenous matter and 72% of water. Fat pork only contains 9.8% of nitrogenous matter and nearly 40% of water. Some of these foods are more digestible, of course, than others. For instance, mutton is said not to be as readily assimilated as beef. Veal is supposed to be liable to produce intestinal disorders. Since fish [1] is both a cheap and nutritious food, it should be used, in many localities, in larger quantities than at present. The United States government is making praiseworthy efforts to introduce the common varieties of food fishes in all the waters of the country, so that fish may be more abundant and cheaper. If we compare the analysis of fish with that of meat, we notice that the nitrogenous part of fish affords more of the gelatin-yielding matter — that is, the collagen — and less extractives than meat. There is also much less hæmoglobin in the flesh and blood of fish than in meat, so the flesh of most fish is of a light color. The mineral matter is usually high, and contains a considerable quantity of phosphates. Fish does not improve, like meat, by being kept, even on ice, but it rather deteriorates.

Fish may be conveniently divided into two classes, — the lean and fat. Some examples of these are the following: [2] —

[1] Bul. 28, Office of U. S. Dept. Agric. Exp. Stations.
[2] Farmers' Bul. 85, U. S. Dept. Agric.

PER CENT OF FAT

Fat Fish		Somewhat Fat		Lean	
Eels	18	Halibut	2 to 10	Cod	0.4
Salmon	12	Mackerel	2 to 9	Haddock	0.3
Herring	8	Mullet	2 to 3	Trout	2.1
Turbot	12			Bass	2.8

There is more waste matter, such as skin and bones, in fish than in meat, and the per cent of water is very high, especially in the lean varieties. As fish contains considerable gelatin-yielding substances, it loses more on boiling than does meat, hence this is not a good method for cooking fish.

Oysters are easily digested, but, as they contain 88% of water, they are not regarded as a valuable food from a purely nutritive standpoint. They contain both carbohydrate (glycogen) and nitrogenous matter, though it is probable that the latter is not all present in the form of proteins. Most of the other shellfish are not as digestible as oysters.

Meats are liable to be dangerous to consumers on account of the diseases with which the animals have been affected. This is especially the case with pork, which is liable to be infected with tapeworms, trichinæ, and other parasites. The only safe method to be employed, if we use pork, is to see that it is thoroughly cooked. Ham, for instance, unless boiled for a long time, is not heated to a high enough temperature to destroy the parasites. Most of the varieties of game are wholesome, and, where abundant enough to be reasonable in price, are very important foods. The same may be said of the so-called sea foods. Many of these furnish the protein bodies in a very concentrated form, so, if we use this kind of food exclusively, it is

not a well-balanced ration. It is a familiar fact that sailors on long voyages or those living in nearly inaccessible regions suffer severely from scurvy if they are obliged to subsist on salt meats without potatoes or other vegetables.

* **Experiment 153.** Procure some "Hamburg steak," and weigh out about 25 grams. Put this into 100 cc. of boiling distilled water and boil for 30 min. Keep the volume of the liquid constant by the addition of more water. Filter, while hot, through a cloth, and wash with hot water until the filtrate measures 200 cc. Evaporate this filtrate in a weighed dish, to dryness, cool, and weigh, and from this calculate the per cent of soluble matter obtained.

* **Experiment 154.** Weigh out a similar amount of steak and add to it 2 grams of salt. Carry out the experiment as in Experiment 153, subtract the 2 grams of salt from the weighed residue, and calculate the per cent of soluble material.

* **Experiment 155.** Weigh about 25 grams of steak, place it in a beaker in 100 cc. of cold water, and digest on a water bath at a temperature not above 80° C. (176° F.) for 2 hr., then filter, and proceed as in Experiment 153. Find the per cent of soluble material.

* **Experiment 156.** Weigh out 25 grams of steak, and treat as in the previous experiment, except adding 2 grams of salt. Find the per cent of soluble material, after subtracting the 2 grams of salt added.

CHAPTER XXII

EGGS

As the egg contains all the substances necessary for the development of the chicken, and to sustain it until hatched, its composition is of special interest. Over 1800 million dozens of eggs are produced annually in the United States. Eggs contain much protein and mineral matter, which is used to furnish the salts of the bones, especially calcium, phosphate, and also fat, one of the most concentrated forms of nutriment. The average weight of a hen's egg is 60 g. (2 oz.), and of this the shell weighs 6 g., the white 36, and the yolk 18. The shell consists mainly of calcium carbonate.

The white always has an alkaline reaction, and consists of a solution of protein inclosed in numerous cells. When the egg is beaten, the cells are ruptured and the protein is set free.

EGG WHITE

According to Church,[1] egg white has the following composition: —

Water	84.8
Albumin	12.0
Fat, sugar,[2] extractives, membranes	2.0
Mineral matter	1.2

[1] "Foods," p. 160.

[2] The amount of sugar is probably not over 0.5 per cent, according to Lehman.

The nitrogenous material or albumin consists of at least four distinct compounds, all quite complex in structure. These contain carbon, hydrogen, nitrogen, sulfur, phosphorus, and oxygen, but it is not at present possible to state their exact formulæ.

EGG YOLK

The yolk is much richer than the white, as the following analysis shows: —

Water	51.5
Casein and albumin	15.0
Oil, lecithin, etc.	30.0
Pigment, extractive, etc.	2.1
Mineral matter	1.4

The composition of the white and yolk together as compared with meat is as follows: [1] —

	Egg	Moderately Lean Meat
Water	73.7	73.0
Protein	14.8	21.0
Fat	10.5	5.5
Ash	1.0	1.0

So eggs may with propriety be used to supplement food rich in carbohydrates and lacking in proteins and fat. Fat "ham and eggs" do not form a well-balanced diet, but potatoes or bread with eggs form a good diet. It is estimated that from 15 to 20 eggs are the nutritive equivalent of 2 lb. of medium fat meat.

For the preservation of eggs, a large number of methods have been proposed, such as packing in bran, coating with vaseline or gelatin, and covering with brine or limewater.

[1] Atwater, Bul. 28, Office of Exp. Sta. U. S. Dept. Agric.

The best method, however, has been found to be by covering with a 10% solution of water glass (sodium silicate).[1] As these eggs break readily on boiling, they should be pierced with a needle before being put into the water.

Desiccated eggs have been recently put upon the market. If fresh eggs are used in this preparation, there is no reason why it should not be possible to furnish a good article of diet, when the water has been driven off by drying in thin layers, in a current of warm air. The temperature employed is one that will give as rapid drying as possible without coagulating the albumin. A good quality of dried egg should contain 7% or less of moisture, 37% of fat, and about 30% of soluble, coagulable proteins.

Most of the so-called "egg substitutes" and "custard powders" consist chiefly of starch, dried skimmed milk, and turmeric, a yellow coloring matter or Victoria yellow; they are, of course, worthless as "substitutes."

There is a popular notion that hard-boiled eggs are not digestible, and experiments made with eggs in the stomach lead to the same conclusion. Thus eggs slightly boiled have left the stomach in one and a quarter hours, raw in two hours, and hard-boiled in three hours. It should be noted, however, that raw eggs are only partially digested in the stomach, and complete digestion is accomplished farther along in the alimentary canal.

In cooking eggs, especially for invalids, they should be placed in water at 170° to 180° F., and allowed to remain for 10 min. or less, when the yolk will be found to be more coagulated than the white. The egg albumin begins to coagulate at 134° F., and it requires some time to heat the egg throughout.

A convenient method for cooking eggs without the use

[1] Farmers' Bul. 103, Dept. Agric., also Bu. Chem., No. 115.

of a thermometer, is to pour a quart of *boiling* water into a covered vessel and put two or three eggs into this and allow them to remain for five or six minutes. The yolk actually cooks more readily than the white, and by this process the eggs are cooked uniformly throughout.

Experiment 157. Mix some egg white with water, add a drop or two of dilute nitric acid, and notice that it coagulates.

Experiment 158. Shake some egg yolk in a test tube with ether, decant off the clear liquid into a glass evaporating dish and allow to evaporate spontaneously. The egg fat will remain in the dish.

*** Experiment 159.** Prepare some white of hard-boiled egg and when cold rub it through a fine sieve. Place a little of this egg white in a test tube and add to it a little hydrochloric acid (0.2% solution) and some prepared pepsin. Allow the test tube to stand in a vessel of water heated to 40° C. for about an hour. Notice that the egg white gradually dissolves, or in other words the albumin has been gradually changed into peptone.

CHAPTER XXIII

MILK

In its composition milk suggests blood; that is, it is a thin watery fluid in which various bodies are held in suspension and in solution. We can readily see, by the use of the microscope, that the fat globules of milk are thus held in suspension. It has been shown that the richer the milk, the larger these fat globules. The liquid that holds them in suspension is rich in nitrogenous matter and in sugar. As will be seen from an analysis, milk occupies an intermediate position between cereal and strictly animal foods. Of the cereal class, it contains milk sugar and fat; while of the animal class it contains casein and albumin. Milk is slightly alkaline in reaction. On account of the cost of milk in many cities, the poorer classes use only limited quantities. For instance, in London, an estimate made some time since showed from $1\frac{1}{2}$ to $7\frac{1}{2}$ oz. per capita was used weekly, while in Scotland $6\frac{1}{2}$ pt. was used per week. The composition of milk from different animals varies considerably, as can be seen by an inspection of the following table:[1] —

[1] König.

	Spec. Grav.	Water	Casein	Albumin	Total Proteins	Fat	Milk Sugar	Ash
Cow's	1.0315	87.17	3.02	.53	3.55	3.64	4.88	.71
Human	1.0290	87.41	1.03	1.26	2.29	3.78	6.21	.31
Goat's	1.0305	85.71	3.20	1.09	4.29	4.78	4.46	.76
Sheep's	1.0341	80.81	4.97	1.55	6.52	6.86	4.91	.89
Mare's	1.0347	90.78	1.24	.75	1.99	1.21	5.67	.35
Ass's	1.0360	89.64	.67	1.55	2.22	1.64	5.99	.51

The specific gravity of milk ranges from 1.027 to 1.035. A convenient form of apparatus to use in determining the specific gravity is the lactometer, which has a range from 1.015 to 1.040, and is usually standardized at 60° F. (15° C.).

The lactometer was formerly relied upon to detect the addition of water to milk, but since the cream may be partially removed, and then considerable water added to correct the specific gravity, this instrument is not very valuable, except for confirmatory tests.

Experiment 160. Test a sample of milk by a hydrometer or lactometer to determine its specific gravity. Readings taken at other temperatures than 15° may be corrected by a table that has been prepared.

COMPOSITION OF BUTTER FAT

By the saponification of butter fat the following composition was obtained: [1] —

Butyric acid	6.13	Oleic acid	36.10
Caproic, caprylic, and capric acids . . .	2.09	Glycerol (calculated)	12.54
Myristic, palmitic, and stearic acids . . .	49.46		106.32

[1] James Bell, from Allen's "Commercial Organic Analysis," 4th edition, Vol. II, p. 279.

These results, and many others that might be quoted, show that butter fat is practically a mixture of various esters, those of butyric, palmitic, and oleic acids being the most abundant. The amount of stearic acid contained in butter is probably very small. The first four constituents are those which distinguish butter fat from ordinary fats like lard or tallow. It is by the determination of the amount of these that the chemist is able to distinguish between genuine butter and its imitations.

The amount of fat varies from 3 % to 6.5 %, or even 7 %, in normal milk. In some countries any milk having less than 4 % of fat is considered adulterated, but the minimum amount allowed in many cities in the United States is 3 %. The Secretary of Agriculture in consultation with the Association of Official Agricultural Chemists has adopted as a "standard" for milk, that it shall contain not less than 12 % of total solids, and not less than 8.5 % of solids not fat, nor less than 3.25 % of milk fat. The fat in milk can be separated for laboratory purposes by shaking it out with ether, and then allowing the ethereal solution to evaporate.

THE BABCOCK TESTER

A practical method for the determination of fat is the one used in large dairies; that is, by the use of the Babcock tester. This instrument, invented by Professor Babcock of the University of Wisconsin, has proven of immense value to the dairy interests, as it is possible for the producer, as well as the manufacturer, to know exactly the value of the milk. The first milk, called the "fore milk," which is drawn from the udder of a cow, is poor in fat, because the fat globules have risen to the top; but for the

same reason, the "strippings," or last of the milk drawn, is rich in fat.

THE SEPARATOR

The cream may be raised upon the milk by allowing it to stand in shallow pans for a long time, by putting it in deep vessels and keeping it at a comparatively low temperature, or more recently, and more practically, by the use of the "separator." This is nothing but a centrifugal machine so arranged that the lighter cream shall, when the milk is whirled with great rapidity, come to the center and be carried off by a pipe, and the heavier milk shall be thrown to the outside by the same motion, and carried off to a separate receptacle.

KOUMISS

There is a fermented beverage known as "koumiss," made from milk, which should be mentioned. It was originally prepared from mare's milk. It is made by mixing milk with yeast and some sugar, putting it in a bottle, and closely corking it. Fermentation takes place after two or three days, and the beverage is fit for use. It is used as a nourishing tonic for invalids and seldom contains as much as 2% of alcohol.

Experiment 161. Shake 15 cubic centimeters of milk with ether, allow the ethereal layer to separate out, draw it off with a pipette, and allow it to evaporate on a watch glass. This gives quite a pure grade of butter fat.

Experiment 162. Determine the amount of butter fat in several samples of whole milk by the use of the Babcock tester. By the action of oil of vitriol on a measured quantity of milk,

a great amount of heat is evolved, and the mixture turns dark brown upon the addition of hot water; when the bottle is put into a "centrifuge" and whirled rapidly, the fat, which is lighter, collects in the narrow stem of the bottle. The graduations of this stem have such a relation to the quantity of milk used that the per cent of butter fat can be read directly upon it.

TOTAL SOLIDS

The total solid matter in milk is also of use to the chemist in forming an opinion as to whether a sample has been diluted with water or not. The lowest amount of solids usually permitted in normal milk is 12%, but most milk contains from 1 to 3% more.

Experiment 163. Test the sample of milk, the specific gravity of which has been already determined (Experiment 160) for "total solids," by weighing a small glass or porcelain evaporating dish on the horn-pan balance. Weigh into this 5 cc. of the sample, and evaporate for about 2 hr., or until perfectly dry, on a water bath. Weigh the residue, and from this and the known weight of the milk, calculate the per cent of total solids. Reserve the residue for Experiment 166.

CASEIN

The casein of milk exists apparently in the fresh sample as a soluble compound of albumin and calcium phosphate, which by the action of "rennet," a ferment from the calf's stomach, is converted into an insoluble compound known as casein. The casein precipitate of rennet contains from 1 to 1.5% of ash, consisting almost entirely of calcium phosphate. Lactic acid also precipitates the casein, but the precipitate contains less ash than that separated by rennet. Mineral acids also precipitate a casein containing less ash.

The proportion of albumin in milk is always, according to Blyth, about one fifth of the casein.

The proteins of milk contain about 80% of casein, which is not coagulated by heat but is coagulated by acids, about 15% of lactalbumin, which is soluble and coagulates by heat and forms the skin on boiled milk, and a few minor ingredients.

In the souring of milk, which is caused by certain acid-forming bacteria, part of the milk sugar is changed into dextros and galactose, and the latter sugar changes to lactic acid: —

$$\underset{\text{Lactose}}{C_{12}H_{22}O_{11}},H_2O = \underset{\text{Dextrose}}{C_6H_{12}O_6} + \underset{\text{Galactose}}{C_6H_{12}O_6}. \quad \underset{\text{Galactose}}{C_6H_{12}O_6} = 2\,\underset{\text{Lactic Acid}}{C_3H_6O_3}.$$

This coagulates the casein, but when a certain degree of acidity is reached the ferment is killed, and the action stops. This suggests the change that takes place in wines, for there also, as the alcohol increases, the ferment is destroyed. Coagulated milk is frequently used to make a kind of cheese which undergoes what is known as "butyric fermentation," producing an odor that by some is considered very disagreeable.

MILK SUGAR

After the casein has been separated from the milk by means of rennet, the whey, which remains, may be utilized for making milk sugar. The crystals undergo lactic fermentation readily, but alcoholic fermentation with difficulty.

Experiment 164. To 10 cc. of milk add a few drops of rennet, and keep the solution at a temperature of 40° C. for some time. A heavy precipitate of calcium paracaseate (cheese) results.

Experiment 165. Treat a sample of skim milk in a test tube with just enough dilute HCl to cause it to coagulate, keep warm for some time, filter and wash. Burn a little of the "curd" which remains on the filter, and notice, from the odor, its nitrogenous character. Neutralize some of the filtrate (the whey) carefully with sodium hydroxid, and test it for milk sugar.

ASH

The ash of milk consists essentially of phosphates and chlorids of potassium, sodium, calcium, and magnesium — salts that are especially needed for the growth of bone material in the young. A small quantity of citric acid is also found in milk in combination with lime.

STERILIZED AND PASTEURIZED MILK

Although milk which is drawn from a healthy, clean cow by clean hands into a bottle which has been sterilized is a sterile fluid, yet in ordinary practice these conditions are not attained, and ordinary milk contains a variety of microörganisms. Some of these may produce souring and others may be bearers of disease. These organisms can be destroyed by a temperature of 100° C., and a temperature of 75° C. will destroy most of the pathogenic bacteria. This process of heating is known as sterilizing, and although it is advocated for the treatment of milk for infants and invalids, especially in large cities, yet the quality of the milk is decidedly altered.

Some of the changes noticed in sterilized milk are: —

1. A change of taste.
2. The amylolytic ferment is destroyed.
3. The fat is not so easily emulsified, and cannot be so readily absorbed from the intestine.

4. The casein does not coagulate so quickly, and therefore is not as digestible.

5. The lactalbumin is destroyed.

PASTEURIZATION

On account of these changes produced by sterilization the method of Pasteurization has come into vogue, except in those cases where the milk must be kept for several days. Pasteurization consists in keeping the milk at a temperature of 167° F., for 20 minutes, instead of raising the temperature to the boiling point, as in sterilizing. By this process most of the bacteria that are liable to be present in the milk are destroyed, the taste of the milk is not so much altered, and its nutritive qualities are not seriously interfered with. This milk will keep only one or two days under ordinary conditions.

CONDENSED AND EVAPORATED MILK

It is extremely convenient under some circumstances to have at our disposal condensed, or evaporated, milk. This may be made from " whole " milk or from skimmed milk, and it may or may not be preserved with cane sugar. There is one product on the market which is obtained by boiling the milk first in open pans and then in vacuum pans. This product is served to customers fresh, and will only keep for a few days. Another product, one which is more commonly used in the United States, is canned or evaporated milk. This is made by boiling down the milk in a vacuum pan and mixing with cane sugar and sealing in the cans while hot. This product will keep for a long time, but not indefinitely, as it is liable, after a time, to become ropy and unfit for use.

According to a report of the Massachusetts State Board of Health, the following is the analysis of a normal condensed milk: total solids, 74.29%; milk solids, 32.37%; cane sugar, 41.92%; milk sugar, 11.37%; proteins, 8.46%; fat, 10.65%; ash, 1.29%; number of times condensed, 2.3.

United States standard condensed milk should contain not less than 28% of milk solids, of which not less than one fourth is milk fat. Although it must be admitted that in some cases condensed milk can be digested more readily than fresh milk, yet in general its chief defect is that it contains too little fat; that is, the dilution that is necessary on account of the large amount of sugar present, reduces the per cent of fat much below that of normal milk.

One of the newest milk products on the market is "dried milk." This product, as well as "dried cream," is made by feeding continuously a thin sheet of milk between two steam-heated cylinders, revolving in opposite directions, and having a surface temperature above 100° C. The cylinders are slightly separated, and the milk is dried in 30 seconds, and scraped from the rolls by a knife edge. The product is mixed with warm water for use.

MODIFIED MILK

From an inspection of the table given on p. 296, it will be seen that human milk differs from cow's milk in several important particulars. The latter contains a little less fat, considerably less sugar, more proteins, and more ash. On this account a great demand has arisen for cow's milk so modified that it shall approximate human milk in composition. The general method adopted to render common milk better adapted to the feeding of infants is to bring the proteins and ash to the right proportions by

dilution with water, then to increase the per cent of sugar by the addition of lactose, or sometimes cane sugar, and finally to add cream and usually some limewater.

ADULTERATION OF MILK

The most common adulteration of milk is by the addition of water, but the acid of milk is sometimes neutralized by the use of baking soda, or various preservatives may be added to it, especially in warm weather.

Experiment 166. To detect sodium bicarbonate and borax in milk, the residue obtained in Experiment 163 is ignited to obtain the ash. After cooling, add a drop or two of HCl, and notice if there is any effervescence, which would denote the presence of carbonates. Test this acidified solution for borax by soaking in it, for a short time, a strip of turmeric paper, and allowing it to dry on the side of the dish above the solution. If the paper becomes of a dark cherry-red color when dry, and turns dark olive when treated with dilute sodium hydroxid solution, boric acid or borax has been added as a preservative.

Experiment 167. To test milk for formaldehyde, use "Formaldehyde Reagent," which is made by adding to a liter of hydrochloric acid (1.2 specific gravity) 2 cc. of a 10% ferric chlorid solution. Ten cubic centimeters of this reagent is added to 10 cc. of milk in a small porcelain casserole, and the solution is heated, slowly, nearly to boiling, and at the same time a rotary motion is given to the vessel to break up the curd. When formaldehyde is present there will appear a violet coloration, especially when it is partially cooled. The color of this solution will vary with the amount of formaldehyde present. If this preservative is absent, the solution slowly turns brown. This test is said to be delicate to $\frac{1}{250,000}$ if the milk has not soured. After souring the limit of delicacy is $\frac{1}{50,000}$. This test cannot be used when the milk is flavored with vanilla.

CHEESE

The general method of making cheese is by the addition of rennet to milk warmed to about 41° C. Rennet is the name given to an infusion in brine of the middle stomach of the calf. The rennet produces a coagulation of the milk by the action of an enzyme, which acts only in an acid or neutral solution. The coagulated milk, after having been broken up several times in vats by the use of knives and heated to a moderate degree, is inclosed in cloth and the whey is pressed out. After the cheese has become solid, the molds are removed and the cheese is placed in well-aired rooms to cure. The flavor improves with age, from the development of fatty acids and ethers, and by the action of certain bacteria. A peptonizing enzyme has been discovered in milk, and to this is probably due the flavors that are induced in cheese during the process of ripening. As this process continues, the cheese is turned daily and rubbed with oil. This improvement with age suggests what takes place in wines and liquors in the process of aging. Some yellow coloring matter, such as "annatto" or a coal-tar dye, is frequently added to the cheese in the process of manufacture. Cheeses are generally classified as cream cheese, whole cheese, and skim-milk cheeses.

Soft cheeses, like Brie, Neufchâtel, Gorgonzola and Camembert, are made in a short time, and by coagulating with rennet at a low temperature; *i.e.* below 30° C.

Medium cheeses are allowed to drain for some time without pressure. The English "Stilton" and the Swiss "Gruyère" belong to this class.

Hard cheeses, like "Cheddar," and the common cheese of the United States, are made by coagulating at a

higher temperature — 30° to 35° — and then thoroughly pressing.

The names applied to cheeses are frequently those of the locality from which they originally came. Limburger is a soft, fat cheese. Roquefort is made from the milk of the ewe. Parmesan is a dry Italian cheese, with a very large amount of casein, and a moderate percentage of fat. Edam is a Dutch cheese, quite dry, and having a red coloring on the outside. The following compilation by Woll [1] shows the average composition of some common varieties of cheese.

	Water	Casein	Fat	Sugar	Ash
Cheddar	34.38	26.38	32.71	2.95	3.58
Cheshire	32.59	32.51	26.06	4.53	4.31
Stilton	30.35	28.85	35.39	1.59	3.83
Brie	50.35	17.18	25.12	1.94	5.41
Neufchâtel	44.47	14.60	33.70	4.24	2.99
Roquefort	31.20	27.63	33.16	2.00	6.01
Edam	36.28	24.06	30.26	4.60	4.90
Swiss	35.80	24.44	37.40	—	2.36
Full cream (average)	38.60	52.35	30.25	2.03	4.07

It is evident that cheese is made up of about one third water, one third nitrogenous matter, and one third fat. The mineral matter is also of considerable importance.

Cheese is so rich in nitrogenous matter, and also in fat, that it might properly form a valuable food for the poorer classes, while it is used by the more wealthy as a relish. A comparison with other animal foods shows very distinctly its theoretical value as food. It is rather difficult to digest in the stomach, unless finely grated or dissolved, as the fat protects the casein from the action of the digestive fluids. Protein and fat are often much cheaper in cheese than in meat.

[1] *Dairy Calendar*, p. 223.

Rich cheese is very liable to decay, for it furnishes an excellent medium for the growth of living organisms. The poison tyrotoxicon which produces gastro-intestinal irritation and nausea, is developed in milk, ice cream, and cheese when the material is stored in dark, damp, filthy rooms or cellars, or where vessels used for holding the milk are not thoroughly cleaned for use. With proper care of the milk there is no danger of the development of this poison.

About the only falsification of cheese, aside from the fraudulent sale of skim-milk cheese for full-cream cheese, is the so-called " filled cheese," which is made by working into the material in the process of manufacture some foreign fat, as oleo or lard.

BUTTER AND BUTTER SUBSTITUTES

Commercial butter is somewhat granular in appearance, and this is considered a very valuable quality of butter. It has a fragrant odor and an agreeable taste. It contains more or less casein, which causes it to undergo decomposition if the butter has not been thoroughly washed. Butter must be salted in order to preserve it for any length of time. The composition of butter fat has been noted under the discussion of milk. The proportion of these different fats varies within slight limits, and on this account it is not difficult to distinguish between natural butter and oleomargarin, or a butter that has been adulterated with other fats. Cream which is obtained by the use of the separator should be allowed to ripen for some time before it is churned into butter. In this process of ripening, certain bacteria take an active part, and to such a degree is this the case that the variety of bacteria in the dairy affect very materially the quality of the butter. In-

deed it has become the custom in some dairies to import bacteria, or some material containing bacteria of a specially high grade, so as to make a fine quality of "June butter."

On the continent of Europe the people purchase butter every day for a single day's supply, as the butter is never salted, and as it usually contains considerable buttermilk it will not keep. Butter has the average composition: water, 13.59%; fat, 84.39%; casein, .74%; milk, .50%; lactic acid, .12%; and salts, .66%.

RENOVATED BUTTER

"Renovated," or "Process," butter is, in general, made as follows: Old, rancid, and unsalable butter is melted in a large tank, surrounded by a hot-water jacket, at a temperature of about 45° C. The curd and brine are then drawn off at the bottom and the scum is taken off from the top. Air is blown through the mass, to remove the disagreeable odor, and, after mixing with some milk, the mass is churned, and then run into ice-cold water so as to make it granular in structure. The butter is then ripened, worked to free it from buttermilk, and salted. Some states require that this should be marked "Renovated Butter" when exposed for sale, while others allow dealers to handle this product without restriction.

OLEOMARGARIN

The manufacture of artificial butter, butterine, or oleomargarin has received encouragement, both in the United States and abroad, on account of the low cost, and also because the imitations are frequently better and more palatable than low grades of cheap butter. The materials used in the manufacture of artificial butter are: "neutral" or leaf lard, from 25 to 60%; oleo oil, from 20 to

50%: some vegetable oil, like cottonseed oil, from 5 to 25%; milk or cream, from 10 to 20% ; butter, from 2 to 10 or 12%: salt and annatto or aniline coloring matter. For different grades of oleomargarin different quantities of these substances are used.

" Neutral " is made by melting leaf lard, and allowing it to " grain " by letting it stand at a temperature favorable for the separation of the stearin in coarse grains. Oleo oil is made in immense quantities, both for use in the manufacture of butterine in the United States, and for shipment abroad. The process of manufacture is to cut the beef fat into small pieces and " render " it in water-jacketed kettles at the lowest possible temperature that is practical. The scum which separates at the top is drawn off and the scraps settle to the bottom. The liquid fat is then run into vats, where it becomes partially cool. The semiliquid mass is wrapped up in cloths and pressed to remove the liquid oil from the solid fat. The solid fat, known as oleo-stearin, is used in the tanning and leather trades, by candle makers, for the manufacture of soap and of " compound " lard. The oleo oil is used in the manufacture of oleomargarin.

For the manufacture of oleomargarin certain proportions of the ingredients, mentioned above, are churned and run into ice water to cool the mass rapidly, and then worked like ordinary butter. The particular variety made depends upon the market. The manufacturers exercise great care that the process shall be a cleanly one, and most authorities agree that a good quality of butterine is better than a bad quality of butter.

At the instance of the dairy interests of the United States, however, a tax probably intended to be prohibitory has been levied upon butterine. This tax is very small, $\frac{1}{4}$ of a cent per pound in case the butterine is not colored,

but if it is colored in imitation of butter, the tax is 10 cents. Until this law was passed, the manufacture of butterine constantly increased, even though the industry was obliged to bear a small tax. In 1903 the total product of oleomargarin was but 71,237,438 lbs., while the previous year it was 123,133,852 lbs.; in 1915 it had increased to 143,268,730 lbs.

Experiment 168. Place about 5 grams of butter in a small flask, add to it 30 cc. of a solution of potassium hydroxid in alcohol, and warm on a water bath. After the soap has had time to form, and while some alcohol still remains, add about 30 cc. of dilute sulfuric acid, and warm the solution. Notice the peculiar odor of butyric ether, especially if the solution is allowed to stand.

Experiment 169. Foam test for purity of butter. Heat about 3 grams of the sample in a large iron spoon over a low Bunsen flame, stirring constantly. Genuine butter will boil quietly, with the production of considerable froth or foam, which may, on removal from the flame, boil up over the side of the spoon. Renovated butter or oleomargarin will sputter and act like hot fat containing water, but will not foam. Examine also the curdy particles when the sample is removed from the flame; in the case of genuine butter these particles are small and finely divided, but in the case of oleomargarin the curd will gather in large masses.

Experiment 170. To make the "milk" test for butter, place about 60 cc. of sweet milk in a wide-mouthed bottle, which is set in a vessel of boiling water. When the milk is thoroughly heated, a spoonful of the butter is added and the mixture is stirred until the fat is melted. The bottle is then placed in a dish of ice water, and the stirring continued until the fat solidifies. If the sample is butter, either fresh or renovated, it will be solidified in a granular condition and distributed through the milk in small particles. If, on the other hand, the sample consists of oleomargarin, it solidifies practically in one piece, so that it may be lifted by the stirrer from the milk.

By the two tests just described, the first of which distinguishes fresh butter from process or renovated butter and oleomargarin, and the second of which distinguishes oleomargarin from either fresh butter or renovated butter, the nature of the sample examined may be determined.[1]

Experiment 171. To test for coal tar colors in butter, a small sample is mixed on a porcelain plate with Fuller's earth, and if these colors are present, there will be a red mass, while if absent, the color will be only light yellow or brown.

[1] Bigelow and Howard, U. S. Dept. Agric., Bu. Chem., Bul. 100, p. 51.

CHAPTER XXIV

NON-ALCOHOLIC BEVERAGES

The ordinary beverages, not including milk, may be classified as non-alcoholic and alcoholic.

From the earliest time there has been a demand for some slightly stimulating beverage that is non-intoxicating in character. The simple herb drinks, such as catnip tea, sage tea, sassafras tea, etc., have been used and are more agreeable than hot water alone, which in itself is slightly stimulating. In different countries and under different conditions, people selected certain plants which seemed to be stimulating in their effects, and made beverages from them. It was later found out that the plants so selected contained certain active, crystalline principles which were stimulating in character.

The most important beverages at present in use are tea, coffee, and cocoa. The imports of tea for the year ending June 30, 1915, were 96,987,942 pounds valued at $117,512,619. The importation of coffee for the same year amounted to 1,118,690,542 pounds, valued at $106,765,644, and that of cocoa products was 194,734,195 pounds, valued at $23,478,156.[1] The per capita consumption of these beverages for a single year was for tea 1.30 lbs., for coffee 10.79 lbs. In Great Britain the per capita consumption of tea is four times that of the United States, while the per capita consumption of coffee is only one

[1] Year Book, U. S. Dept. Agric., 1915.

tenth that of the United States. The use of tea is, however, increasing in this country.

TEA

About 51% of our tea comes from China and 42% from Japan. The history of the discovery of tea is lost in antiquity. The first authentic account was as late as 350 A.D., while in European literature the earliest record appears in 1550. The first consignment of tea into England took place in 1657, and it came into the United States in 1711. Genuine tea is prepared from the leaf of the *Thea sinensis*, a plant which grows to the height of 4 to 5 ft. The leaves are ready for picking at the end of the third year, and the average life of the plant is about 10 years. The leaves are picked at least three times per year, —in April, May, and the middle of July. The first pickings are the best and tenderest, and make the best grade of tea.

CURING OF TEA

After sorting, the natural moisture is partially removed by pressing and rolling, then the leaves are dried by gently roasting in an iron pan for a few moments. They are then rolled on bamboo tables and again roasted, and finally separated into the various grades by passing through sieves.

The difference between green and black tea is mainly due to the fact that the green is steamed thoroughly and then rolled and carefully fired, whereas black tea is first made up into heaps which are exposed to the air and allowed to ferment, and thus the olive-green is changed into a black color.

In the preparation of Japan tea, the leaves are steamed in a tray over boiling water. They are then heated on a tough paper membrane over an oven and at the same time stirred with the hand. The tea after being thus fired is dried for some hours and sorted by passing through sieves. Then it is sent to the warehouse, where sometimes the " facing process " is carried on, by heating the tea in large bowls and adding various pigments to it.

ADULTERATION

There are but few spurious teas on the market, but the range in quality is very great. On account of the strict enforcement in the United States of the adulteration act, no adulterated tea is permitted to be imported, and the consumer is reasonably well protected. He usually secures genuine leaves though he may get very inferior grades of tea.

Tea, supplied to the foreign market, is exposed to a large number of sophistications and adulterations, mainly for giving it an increased weight. These adulterations include adding foreign leaves, spent tea leaves, metallic iron, sand, brick dust, etc.

Such substances as catechu or similar materials that contain tannin, are added to produce an artificial appearance of strength. Another sophistication, which is practiced especially on green tea, consists in imparting a bright appearance to inferior tea by means of coloring matter or facing; for this purpose they use soapstone, gypsum, Prussian blue, indigo, turmeric, and graphite. Another form of sophistication is practiced on exhausted tea leaves by a similar process of facing. It is even said to be possible, by careful manipulation, to change black tea to green and *vice versa*.

VARIETIES OF TEA

The Indian teas are very much stronger than those from China and Japan, so that they produce a beverage that seems too strong to those accustomed to Chinese and Japanese teas. The Indian teas only come in contact with the hands of the workmen at the time of picking. The Chinese teas are manufactured almost entirely by hand, although sometimes the feet are used in rolling the cheaper grades.

A substance called " lie tea " is frequently put upon the foreign market. This consists of fragments of genuine leaves, foreign leaves, and mineral matter held together by a starch solution and colored with various preparations.

In England black teas are used much more than the green. This is due to the fact that black teas contain less astringent matter and also act less upon the nerves. By comparison of analysis of black and green tea it is evident that there is less material soluble in hot water in the former.[1]

	Green Tea	Black Tea
Crude protein . .	37.43	38.90
Fiber	10.06	10.07
Ash	4.92	4.93
Thein	3.20	3.30
Tannin	10.64	4.89
Total nitrogen . .	5.99	6.22

The important constituents are the extract, a certain amount of tannin and thein, and the volatile oil. On account of the presence of a large amount of tannin in tea,

[1] Analysis by Kozai: W. G. Thompson, "Practical Dietetics," p. 211.

which is extracted by heating with water, it is important, in making the beverage, that the water should not stand for any length of time upon the leaves. On this account a much more wholesome beverage may be made by the use of the tea-ball with the hot water. It is a great mistake to allow the tea to draw for hours at a time. Freshly boiled water should be used in making tea, and it should be thoroughly boiling when poured upon the leaves, and allowed to digest about three minutes, not longer. Longer infusion will make the tea appear stronger but will spoil its delicate flavor, and extract too much tannin, which will have an injurious effect on the system. The water used should not be too soft, as that will extract more soluble material, nor should it be extremely hard. The thein is practically all extracted from tea within the first five minutes, while the amount of tannin continues to increase for 40 minutes or more. The infusion should be poured off from the grounds as soon as made.

According to Hutchison an ordinary cup of tea will contain nearly a grain of thein, and from 1 to 4 grains of tannin, dependent on the kind of tea used. There is no direct relation between the quality or price of the tea and the proportion of thein. This substance, thein, which has the formula $C_8H_{10}N_4O_2$, is an ureide belonging to the same general class as guaranin, xanthin, uric acid, etc. The volatile oil which is present gives to the tea its agreeable flavor and aroma.

Experiment 172. Make a decoction of tea in a test tube, pour it off from the grounds, and test a part for tannic acid.

First, by ferric chlorid;

Second, ferrous sulfate;

Third, by a mixture of these two reagents.

A black or bluish black color (ink) will be produced.

PARAGUAY TEA

There is another variety of tea known as Paraguay tea, or Yerba Maté, which was selected by the people of South America to use as a beverage. This tree grows wild, and is known to the botanist as *Ilex paraguayensis*. The tea is prepared in Paraguay by cutting off the small twigs and leaves and placing them on a clean plot of earth surrounded by fire. In this way the leaves are wilted and cured, and they are afterward dried on a grating over a fire, and then reduced to a coarse powder. The infusion, which is prepared in a kind of gourd, is conveyed to the mouth by means of a reed or a silver tube called a " bombilla," with a strainer at the end.

Maté contains 1.3 % of thein and 16 % of tannic acid, also an aromatic oil and gluten. The tannic acid has entirely different properties from that contained in tea or coffee.

COFFEE LEAF TEA

In some coffee-growing countries the natives use the leaves of the coffee tree to make an infusion which has about the same constituents and properties as ordinary tea.

COFFEE

Coffee is the seed of the *Coffea arabica*, indigenous in Abyssinia and Arabia, and this plant, at the present time, is grown in Java, the West Indies, in Ceylon, Mexico, and Central and South America. It was used in the remotest time in Arabia. It was introduced into Constantinople in 1574; in 1660 it was carried from Mocha to Java, and thence specimens of the tree were taken to Holland and

France. Coffeehouses were opened in London about the middle of the seventeenth century. In 1809 the first cargo was shipped to the United States. There is a great difference in the quality and flavor of coffee from different localities.

The coffee tree is productive for about thirty years. The trees are usually planted every twenty years and grow best on the uplands. The trees are raised from seeds in nurseries and transferred to the plantations. In Java the picking of the berry begins in January, and lasts three or four months; in Brazil, the picking begins in April and May, and continues throughout the season. After the berries are harvested, the first operation by which they are treated is called pulping. Sometimes the berries are pulped in the soft state, sometimes they are first dried, and then the dried skins are removed by a machine called a huller. The West Indian and Brazilian method is to macerate the berries in a large vat, where they are treated by what is known as a pulping machine, which is an iron cylinder set with teeth, which removes the outer covering. The loosened pulp is carried out at one side and the berries sink to the bottom of the vat. The berries are afterward dried, cleaned, and sorted.

The next process is the roasting of the bean. This may be carried on directly over a fire or in an oven. The average loss of weight in the process of roasting is about 16%. This process develops an essential oil and brings out the aroma of the coffee. If the operation is carried too far, the best properties and ingredients are lost.

The following analysis by König shows the difference between raw and roasted coffee: —

	Per Cent	
	Raw Coffee	Roasted Coffee
Water	11.23	1.15
Caffein	1.21	1.24
Fat	12.27	14.48
Sugar	8.55	.66
Cellulose	18.17	10.89
Nitrogenous substance	12.07	13.98
Other non-nitrogenous matter	32.58	45.09
Ash	3.92	4.75

The effect of roasting is to drive off a large part of the water, and to caramelize most of the sugar. The bean becomes more brittle, and the caffeol [1] ($C_8H_{10}O_2$), to which coffee largely owes its odor and flavor, is, at the same time, developed. The active principle, called thein, or caffein ($C_8H_{10}N_4O_2$), is believed to be identical with that of tea. The infusion of coffee also contains some nitrogenous material.

ADULTERATION

Ground coffee is especially liable to be adulterated. Some of the chief substances added to the commercial ground coffee are chicory, caramel, peas, and roasted grains, such as corn, wheat, and rye. There has also been found upon the market an artificial coffee bean which contains absolutely no coffee, and is made by compression of harmless, starchy ingredients into the form of the coffee bean. This is mixed with the genuine beans. The raw coffee bean is sometimes subjected to the process of sweat-

[1] Hutchison, "Food and Dietetics," p. 310.

ing, by which it is increased in size and improved in color and flavor; it is sometimes moistened with water containing a little gum and colored with various pigments, such as Prussian blue and turmeric, so as to improve its appearance. In this way, for instance, Mexican coffee is made to resemble Java coffee.

THE BEVERAGE

In regard to making the beverage there are two common methods, either of which may be used. The first is to put ground coffee into cold water and bring the decoction to the boiling point. The second, and probably better, method is to have the water boiling tumultuously and add to it the required amount of finely ground coffee, boil not more than three minutes, and then serve immediately. The beverage is also made by "percolation" or pouring boiling water through the finely ground coffee, and by a "decoction" process which is the method employed in preparing Turkish coffee. If the coffee is allowed to boil for any length of time, not only is the tannin extracted from the berry, but the agreeable aroma and flavor is lost, as it is carried off with the volatile oil. The coffee is then not as wholesome, and it certainly is not as agreeable in flavor.

Many persons find that black coffee produces less ill-effects upon the system than does coffee served with cream. This may be due to the compound produced by the action of the tannin of the coffee upon the protein substances of the milk. *Café au lait*, which is a mixture of three parts of hot milk with one part of coffee, is a popular beverage in many countries. It will be noticed that coffee contains less of the alkaloid than tea.

There is no great objection to the substitutes for coffee

that are upon the market, if they are not bought as coffee. Many of these are no doubt wholesome enough, and if coffee has been found to disagree with the system, it is probably better to use some beverage of this kind, which is simply an extract of a roasted cereal.

VARIETIES OF COFFEE

There are many varieties of coffee upon the market, but the Mocha and Java coffees usually command the highest price. Comparatively small quantities of these coffees are at present available, but coffee grown in other countries from the Mocha or Java stock is more abundant. The low grades of coffee have decreased very much in price during the last few years. This is probably due to the competition, and, also, to the fact that immense quantities of the cheaper grades are raised in South and Central America. The latest official report shows that three fourths of the coffee imported into the United States comes from Brazil. Some persons have become accustomed to the strong black coffee made from the Rio brand, and to meet their demand, in "blending," some Rio is often added to other grades.

COCOA AND CHOCOLATE

The raw material from which cocoa and chocolate is made, is the seed of the *Theobroma cacao*. It grows most readily from Mexico to Peru on the west coast of the American continent, in Mexico and Brazil on the east coast, and in the West India Islands. It was introduced into Europe by the Spaniards in 1519. Chocolate was first prepared in the United States in 1771, at Danvers, Mass.[1] The tree is about 18 or 20 ft. high, blooms con-

[1] Harrington, "Practical Hygiene," p. 174.

tinuously, and yields two crops a year. The lemon-yellow fleshy fruit is about 7 in. long, something like a short cucumber in appearance, and has ten longitudinal ridges. The seeds are arranged in five rows in the pulpy flesh. There are two processes for preparing the seed for the market. For unfermented cocoa the seeds are separated from the pulp and dried in the sun; for the fermented cocoa the seeds are placed in piles and allowed to ferment, before being dried. Much of the acridity and bitterness disappears in this process of fermentation. The principal operations in the process of manufacture are, first, the sifting of the raw cocoa to remove the sand and dust; second, the separation by hand of the larger stones and empty pods, etc.; third, roasting the cleaned seeds.

The following table[1] shows the composition of some cocoa products: —

	Pure Cocoa, Average of 26 Analyses	Cocoa Shells (Hand Shelled), Average of 17 Analyses	Pure Plain Chocolate, Average of 6 Analyses	Pure Sweet Chocolate, Average of 12 Analyses
Water	6.23	4.87	3.78	2.17
Ash	5.49	10.43	3.15	1.40
Theobromin	1.15	.49	.78	.35
Caffein	.16	.16	.13	.08
Other nitrogenous substances (protein)	18.34	14.46	12.36	4.58
Crude fiber	4.48	16.55	2.86	.95
Sugar	—	—	—	56.44
Pure starch	11.14	4.13	18.11	2.88
Other nitrogen-free substances	26.32	46.15	16.64	7.64
Fat	26.69	2.76	52.19	23.51

[1] Rep. Conn. Agric. Exp. Station, 1903, Pt. II, p. 125.

Cocoa is not only used to make a pleasant and exhilarating beverage; it is a valuable food material. The most important constituents are fat, theobromin, which is the alkaloid or, properly speaking, the ureide of cocoa, a little starch, and some albumin and fibrin. The fat usually forms about 50% of the husk and bean. It is a mixture of the glycerids of stearic, palmitic, lauric, and arachidic acids, and is extensively used in pharmacy under the name of "cocoa butter." Theobromin, which was discovered in 1841 by Woskresensky, is very closely related to xanthine, being dimethyl xanthine, $C_5H_2(CH_3)_2N_4O_2$. Caffein is trimethyl xanthine, $C_5H(CH_3)_3N_4O_2$.

COMMERCIAL PREPARATIONS

The commercial preparations of cocoa are quite numerous. Plain chocolate is prepared by grinding roasted and husked seeds to a paste and pressing in the form of cakes. When this is combined with sugar, vanilla, etc., sweet chocolate is the product. Since there is so much fat in the cacao, this is frequently partially removed, and the residue is put on the market under the name of cocoa. Cocoa shells or husks are sometimes used for making an exceedingly weak beverage of this class, which contains little fat, but considerable nitrogenous matter and extractives. Cocoa "nibbs" are the bruised, roasted seeds, and contain all the fat. The names that are applied to the different preparations of cocoa and chocolate vary in different countries. Cocoa and chocolate preparations are very readily adulterated, but, after all, the general adulterants, if such they may be called, are sugar and starch, which are not injurious, but only decrease the cost for the benefit of the manufacturer. The genuine or "bitter" chocolate should contain all the original fat. An inferior

vanilla chocolate is flavored with the artificial vanillin and coumarin in place of the finer flavored vanilla bean.

It is said that the term " soluble cocoa " is erroneous, as very little of the albuminous substances or the fat are soluble. In order to grind the bean to a very fine powder it must be mixed with sugar or starch, and this, in fact, is the method used in the preparation of some of the powders recommended for invalid diet. Sometimes, in order to make a cocoa that shall be more digestible, a part of the fat is saponified by the use of sodium hydrate and magnesia, a process that may in some cases produce a food that is less digestible than the product that is not so treated.

Sweet chocolate, especially by reason of the sugar that is added, has a high food value. Chocolate does not, like tea and coffee, produce wakefulness, though, on account of the large amount of sugar and fat which it contains, it may produce indigestion. As chocolate is a concentrated food, it may be conveniently used when the weight of food to be carried must be considered, as on the march, or on camping expeditions.

Experiment 173. Shake a few grams of powdered chocolate in a test tube with ether, filter, on a dry filter, and allow the filtrate to evaporate spontaneously in a glass evaporating dish. Notice the taste and odor of the fat or " cocoa butter " that remains. Notice also that cocoa butter gives a clear solution with ether, while wax or tallow gives a turbid solution.

Experiment 174. Boil a few grams of powdered chocolate with water, filter off 10 cc., and treat the cold solution with iodin reagent for starch.

COLA

The cola nut grows on a small tree in several tropical countries, especially Jamaica, Africa, East India, and Cey-

lon. It contains caffein, theobromin, tannin, and the other constituents of tea and coffee. As a beverage it is made into an infusion like coffee, and is served with milk and sugar.

COMPARISON OF THE COMMON STIMULATING BEVERAGES

These beverages possess qualities in common for which they are universally esteemed by mankind. First, they retard the retrograde metamorphosis of the body tissues, and thus enable the work of the individual to be done upon a smaller supply of food material and with less fatigue.

Second. When used in moderation, they are all more or less stimulating to the mental powers.

Third. They act as sedative to the nervous system. The similarity of the action of these beverages is due to the possession of common constituents. While there are divergences from each other, in their finer shades of action their value depends upon the aromatic and volatile oil which modifies the action of the alkaloid. It is an interesting fact that similar properties are developed in each of them by roasting and drying.

Coffee is more stimulating than cocoa. It is apt to cause irregularity and palpitation of the heart and may, if boiled too long, disorder digestion.

Tea is the most refreshing and stimulating of these beverages. Used in excess, however, it powerfully affects stability of the motor and vasomotor nerves, the action of the heart and the digestive functions, producing dyspepsia, tremulousness, irregular cardiac action, headache, etc.

Maté is supposed to be intermediate in its effects between tea and coffee. Chocolate is more nutritious than tea or coffee on account of the amount of fat which it contains;

although much of this fat is removed in making cocoa. Since but little of the solid is used in making the beverage cocoa or chocolate, the food value is not very great. Cocoa and chocolate are only slightly stimulating in their effects.

Cola probably has a restraining influence on tissue waste and is mildly stimulating to the heart and nervous system. As it will increase the endurance, it may be used when severe muscular exercise is to be undertaken.

When we consider the whole subject of beverages of this class, it is extremely interesting to notice that uncivilized people and civilized people in different ages of the world, in different climates, and under entirely different circumstances, have chosen plants to use in the manufacture of beverages that contain these alkaloid principles; caffein in the case of tea, coffee, and cola, and theobromin in the case of chocolate. Most of them also contain the astringent principle tannin. The use of these beverages has increased from year to year in all civilized countries.

CHAPTER XXV

ALCOHOLIC BEVERAGES

It is probably true that alcohol, as such, is not found in sound fruit, yet alcohol is so readily formed by the process of fermentation from cane or fruit, that it was not strange that it was accidentally discovered, and that beverages having intoxicating qualities should have been used very early in the history of the world. Alcohol, C_2H_5OH, is a colorless liquid, having an agreeable odor, burning with a blue flame, and having a specific gravity of .792. Ordinary alcohol is about 95% strength, and the remaining 5% is water. Proof spirit, as it is called, contains 42.50% of alcohol by weight or 50% by volume. This was originally named from being the most dilute spirit which when lighted would fire gunpowder.

The annual consumption of alcoholic beverages, per capita, in the United States, and in several other countries, in 1906 to 1910,[1] was: —

	Liters		
	Beer	Wine	Spirits
Great Britain	143.	1.23	4.17
France	71.6	144.	8.82
Austria-Hungary	134.	19.8	8.20
Japan, all liquors (mostly saké)			16.21
United States	76.2	2.37	5.51

[1] "Alcohol and Society," John Koren.

The Statistical Abstract of the United States for 1915 reports the per capita consumption of distilled spirits to be 1.25 proof gal.; that of wine, 0.32 gal.; and that of malt liquors, 18.24 gal. There was until recently a notable increase in the consumption of malt liquors from year to year.

CLASSIFICATION

Alcoholic beverages may be made from any vegetable product that contains starch or sugar. There are four general classes, viz.: —

1. Fermented liquors: as wine, cider, perry; wine from fruits, berries, etc.; palm wine, called "toddy" in India; bouza, made in Tartary and the East from millet seed; honey wine, used in Abyssinia; koumiss, made from mare's milk in Tartary; fig wine, made in the vicinity of the Mediterranean Sea; and pulque, made by the Mexicans from the juice of the century plant.

2. Malt liquors: as lager beer, ale, porter, stout; kvass, made in Russia from rye; chica, made in South America from corn, rice, etc.; saké, made in Japan from rice; and pombe, made in Africa from rice.

3. Distilled liquors: as alcohol, whisky, brandy, gin, and rum, and vodka made from grains in Russia, arrack made from rice and palm juice in India, mescal or pulque brandy, and cherry brandy, or "Kirschwasser," as it is termed, in Germany.

4. Liqueurs and cordials: as absinthe and vermuth.

The fermented liquors are made from the juices of fruits, which contain sugar, and they require no yeast to start the fermentation, but depend on the organisms which are present in the natural juices. Most of the sugar present in fruits is in the form of invert sugar. As the quantity of

alcohol that can be obtained from any fruit juice is dependent on the amount of sugar contained, a consideration of the sugar content is important.

The following analyses, by Fresenius, show the amount of sugar and acid in the common fruits: —

	Per Cent Sugar	Per Cent Free Malic Acid
Grapes	16.15	.80
Sweet cherries	15.30	.88
Sour cherries	10.44	1.52
Mulberries	10.00	2.02
Apples	9.14	.82
Pears	8.43	.09
Gooseberries	8.00	1.63
German prunes	7.56	1.08
Currants	7.30	2.43
Strawberries	6.89	1.57
Blackberries	5.32	1.42
Raspberries	4.84	1.80
Green grapes	4.18	.67
Plums	2.80	1.72
Apricots	2.13	1.25
Peaches	1.99	.85

WINE

The most important of the fermented beverages is wine. The cultivation of grapes, for the purpose of making wine, began in the East in the earliest times, and extended along the shores of the Mediterranean Sea. Germany, Austria, Greece, France, Italy, Spain, and Portugal are the continental wine-growing countries, while in the United States the industry is of great importance in Ohio, New York, Virginia, and California. The quality of the wine depends on the variety of grapes, the soil, climate, and even on the weather.

In order to make genuine wine, the grapes are allowed to ripen, so that they contain as much sugar as possible. The grapes are carefully crushed and pressed, and the first juice that runs off produces the best quality of wine. The "marc," as the pulp is called, is sometimes pressed several times after being soaked with water, and this affords cheaper qualities of wine. The "must," as the expressed juice is called, is allowed to ferment from 10 to 30 days. Fermentation begins at from 10° to 15° C., and is brought about by the germs which grow at the expense of the saccharine and albuminous substances present, and change the sugar to carbon dioxid and alcohol. Thus: —

$$\underset{\text{Sugar}}{C_6H_{12}O_6} = 2\ \underset{\text{Alcohol}}{C_2H_6O} + 2\ \underset{\text{Carbon Dioxid}}{CO_2}.$$

After the first fermentation, the wine is drawn off from the "lees" and put in casks, where the after fermentation takes place. The "lees" consist of the fungus growth, some calcium salts, coloring matter and "argols," potassium bitartrate, or "cream of tartar," which is insoluble in dilute alcohol. This is the only practical source of cream of tartar; consequently this chemical commands a good price.

From 69 lb. to 70 lb. of "must" can be obtained from 100 lb. of grapes. The quantity of sugar in the juice varies from 12 to 30%. It is of importance that the ferment be of a certain kind to produce a good wine; and, indeed, the bacteriologist has begun to propagate special cultures of a pure yeast to produce wine of a desired flavor. The wine is stored in casks for some months, for the process of aging. Before being placed in the cask, the wine is treated with isinglass, or egg albumen, and "racked off" from the deposited impurities. It must not be too freely exposed to the air, as there is danger that the alcohol, by the aid of

the acetic ferment, shall be changed to acetic acid, according to the reaction, —

$$C_2H_5OH + 2\,O_2 = C_2H_3O.OH + 2\,H_2O.$$

During the aging process a variety of fragrant ethers, as acetic ether, malic ether, etc., are formed, which produce an agreeable odor or bouquet. Wines are sometimes aged and at the same time preserved, by pasteurization, which consists in heating them for some time at 60° C., with a limited supply of air.

In regard to the changes that take place in the cask, Leach observes that the alcoholic strength of the wine rises. This is due to the fact that the water of the wine soaks into the wood more than the alcohol and is lost by evaporation, so that the wine becomes more concentrated. As the water so lost is replaced by the addition of more wine, the increase in the proportion of alcohol is rendered all the greater. In the cask, too, a partial oxidation of the tannic acid takes place. This causes the white wines to become darker in color, but has just the reverse effect upon the red wines; for the oxidized tannic acid unites with and precipitates some of the pigment.

STRENGTH OF WINE

The alcoholic strength of the wine is somewhat increased by a further fermentation of the sugar. By the oxidation of some of the alcohol to acetic acid, compound ethers are formed. There is an impression that wine continues to improve with age, and "old wine" is highly prized. Some of the stronger wines improve for a few years, but not for an indefinite time, and wines often begin to deteriorate after a short time. The "extract," as the term is used below, is what remains upon evaporation.

The following table gives the composition of a few wines: —

Composition of Wines

	Alcohol	Extract	Free Acid, Tartaric	Sugar	Ash
French red .	7.80	2.97	.58	.46	.25
French white	10.84	1.26	.44	.88	.20
Spanish red .	12.34	3.84	.57	.25	.75
Calif. red .	10.03	2.11	.64	.25	.34
Calif. white .	11.16	11.80	.63	.20	.17

Sweet Wines

	Alcohol	Extract	Free Acid, Tartaric	Sugar	Ash
Champagne .	9.50	14.34	.58	.75	.16
Port . . .	16.29	8.30	.38	6.26	.25
Sherry . .	15.93	5.00	.48	2.76	.56
Madeira . .	15.49	5.61	.41	3.18	.33

CLASSIFICATION OF WINE

Wines are either natural or "fortified." Natural wine contains no added alcohol or sugar. When the pure juice of the grape is allowed to ferment, if it contains sufficient sugar, the amount of alcohol will continue to increase until the wine contains about 15%, and this amount of alcohol prevents any further fermentation. Hock and claret are usually of this class. When alcohol is added to the wine, it is said to be "fortified." Port and Madeira are often treated in this way.

Wines are divided into red and white wines, from the

color; also into dry wines, or those in which all the sugar has been changed to alcohol; and sweet wines, or those in which some sugar still remains, although these are often reënforced by the addition of grape sugar. Dry wines are consequently slightly sour. Wines are also divided into "still" wines, or those in which the carbon dioxid gas has been allowed to escape; and effervescent wines, in which the carbon dioxid has been retained in the liquid under pressure.

Grapes make better wine than other fruit because the potassium bitartrate ($KHC_4H_4O_6$) is precipitated as the alcohol becomes stronger in the process of fermentation. Other fruits and berries, on the other hand, contain citric, malic, or succinic acids, and the salts of these are not precipitated during fermentation, and so this wine has not the agreeable taste that characterizes grape wine.

ADULTERATION OF WINES

The adulterations of wine are very numerous. Plaster of Paris is often used abroad for the adulteration of wines, but native wines and those imported into the United States are usually free from this material. This is done, it is said, to clarify it, to improve the color, to make the fermentation more complete, and to improve the keeping qualities. On the other hand, this process is supposed to leave some injurious compounds in the wine. The reaction due to "plastering" is as follows: —

$$2\,KHC_4H_4O_6 + CaSO_4 = CaC_4H_4O_6 + H_2C_4H_4O_6 + K_2SO_4.$$

Pot. Bitartrate — Cal. Sulfate — Cal. Tartrate — Tartaric Acid — Pot. Sulfate

In France there is a law against the addition of more than a limited quantity of plaster of Paris to wines intended for home consumption. Not over .2 % of potassium sulfate is

allowed to be present. The wine manufacturers also burn sulfur in the casks so that the sulfur dioxid shall artificially age the wine. This tends to decrease the number of germs that would be injurious in fermentation. The addition of cane sugar, called " chaptalising " in France, is practiced, under certain very carefully guarded conditions, to increase the yield of alcohol, and commercial glucose is used in the same way. In Germany the addition of sugar to " musts " deficient in this material is permitted. A cheap wine is sometimes put upon the market which contains no juice of the grape whatever, but is made from cider as a basis, to which is added alcohol, tannin, glycerin, glucose, cream of tartar, orris root, ethereal oils, and frequently œnanthic ether. An extract is frequently made from raisins, which is colored and flavored to imitate wine.

Wine is subject to numerous diseases, such as souring, ropiness, bitterness, and molding. Poor wines or those that have deteriorated are sometimes distilled to make brandy.

The total wine production of the world in 1913 was nearly 4,000,000,000 gallons, only one one-hundredth of which was produced in the United States.

Experiment 175. Test a small portion of wine or grape juice in a test tube for grape sugar, by the Fehling test.

Experiment 176. Evaporate 10 cc. of wine or grape juice to one half its volume on a water bath, and to the solution add 50 cc. of a mixture of alcohol and ether. Put this solution in a flask and allow to stand tightly corked for some time, and notice the acid potassium tartrate which crystallizes out.

***Experiment 177.** Acidify a sample of wine with hydrochloric acid, heat to boiling, and add a few drops of barium chlorid. If there is more than a trace of barium sulfate, " plastering " of the wine is indicated. Normal wine does not contain over .06 % of sulfuric acid calculated as potassium sulfate.

CIDER

The fresh juice of the apple, known as sweet cider, is a very convenient solution for growth of the yeast *Saccharomyces apiculatus*, which starts fermentation, and so cider does not long remain sweet. The crushed apples are pressed in a cider press, and the juice is then run off into barrels and allowed to ferment. The refuse left after the juice has been expressed is called " pomace," and is utilized in some other industries. (See p. 270.) In some countries more care is used in the preparation of this beverage, and it is clarified by the use of gelatin and racked off or filtered from the deposited matter. This process tends to improve the quality of the cider.

Cider contains from 3 to 7% of alcohol by volume, besides malic acid, sugar, extractives, and mineral salts.

ADULTERATION AND FALSIFICATION OF CIDER

There are found on the market samples of cider made by adding water to the pomace, and repressing; but this cider is more frequently used as a basis for the manufacture of other beverages. The most important sophistications of cider are water, sugar, and especially the use of preservatives. The preservatives most commonly used are benzoic acid, salicylic acid, sulfurous acid or sodium sulfite, and betanaphthol. Mustard seeds, borax, and horse radish are also used. From some experiments by the author [1] it was shown that the effect of those substances is to retard the fermentation, and not to ultimately prevent it. It is probably true that substances that will retard fermentation will also have a tendency to produce indigestion.[2] (See Chapter XXVII.)

[1] Kan. Univ. Quar., VI, A, p. 111.

[2] Shepard, Report, Ohio Food Commis., 1904.

Perry, or pear cider, is made and consumed more extensively abroad than in the United States. It does not differ essentially except in flavor from cider.

Experiment 178. To test for salicylic acid in cider or beer, acidulate a sample with sulfuric acid and shake with a mixture of equal parts of ether and petroleum naphtha. Remove the ethereal layer with a pipette and allow to evaporate to small volume on a watch glass. Add a little water and a few drops of ferric chlorid solution, when the presence of salicylic acid will be indicated by a violet color.

BEER

This beverage is a representative of malt liquors. According to the best authorities, genuine beer should be made from malt, starchy material, hops, yeast, and water, and nothing else. Malt is made by soaking barley in water for several days, then piling it up on the floor or "couching" till it sprouts and the little radical starts to grow; then the process of germination is retarded by "flooring," as it is called; *i.e.* spreading in progressively thinner and thinner layers upon the floor, and germination is finally stopped by drying the grain. The color of the malt depends upon the temperature at which this drying is conducted. If dried between 32° and 37° C., it forms a "pale malt"; if from 38° to 50°, a brown malt. In the process of malting the albuminous substances of the grain are changed in part to diastase, an active ferment, which has the peculiar property of changing starch to dextrin and then to sugar (maltose). One part of diastase under favorable conditions will convert 2000 parts of starch to sugar.

The next process is known as "mashing." This consists in grinding the malt and soaking it in water at a tempera-

ture of 75° C. The change from starch to sugar is still more completely effected here. The clear infusion, called the " wort," is boiled with hops, and the solution is cooled very rapidly to 18° C. Yeast is added, in the proportion of about 1 gal. to 100 gal. of wort, and the liquid is allowed to ferment about 8 days. It is then drawn off into settling tanks and finally into casks, and stored in a cool place to ripen. The yeast changes the sugar into alcohol and carbon dioxid, in accordance with the reaction : —

$$C_6H_{12}O_6 = 2\ CO_2 + 2\ C_2H_5OH.$$

The sugar is not completely eliminated, as that would interfere with the agreeable taste.

The following analyses of malt liquors, taken from various sources, will give an idea of their composition : —

	Sp. Gravity	Water	Alcohol by Volume	Extract	Sugar (Maltose)	Gum and Dextrin	Acid as Lactic	Ash
Milwaukee lager, bottled	1.0100	—	5.35	4.18	1.10	1.57	.06	.20
H. export	1.0178	—	5.50	6.15	2.14	2.54	.07	.31
Philadelphia ale, bottled	1.0059	—	7.75	3.46	.59	.90	.23	.40
Pilsen lager	—	—	4.10	4.22	.69	2.65	—	—
Munich	—	85.85	5.75	9.40	—	—	—	—
Schenk	1.0114	91.11	4.20	5.34	.95	3.11	.16	.20
Lager (beer)	1.0162	90.08	4.90	5.79	.88	3.73	.15	.23
Export beer	1.0176	89.01	5.50	6.38	1.20	3.47	.16	.25
Bock beer	1.0213	87.87	5.85	7.21	1.81	3.97	.17	.26
Weiss beer	1.0137	91.63	3.40	5.43	1.62	2.42	.39	.15
Dublin stout, XXX	—	—	8.45	9.52	5.35	2.09	.25	—
Porter	1.0191	88.49	5.90	6.59	2.62	3.08	.28	.36
Ale	1.0141	89.42	5.95	5.65	1.07	1.81	.28	.31
Burton bitter ale	—	—	6.80	5.42	1.62	2.60	.17	—

The quality of the beer depends upon the manner of brewing, the temperature, qualities of ingredients, method of storing, kind of water used, quality of the yeast, whether

" top yeast " or " bottom yeast," and the temperature at which it is stored. The lager beer proper, or store beer, should be kept in a cool place for several months before being used. Very much of the beer in use in the United States is what is known as " present use " beer. Bock beer is a strong variety of beer made for use in the spring only, and Weiss beer is a very weak beverage used in Germany. Ale, porter, and stout are richer in alcohol than lager beer.

In the manufacture of beer the tendency is to use as little of expensive ingredients as possible, so in cheap beers, part, or all, of the barley malt is replaced by some other grain, as corn or rye, and even a special kind of glucose is added to furnish a material that will readily ferment. It is asserted that sometimes the bitter principle in cheap beer is also replaced by quassia and other bitter substances. Most of the beer on the market contains from 2 to 5% of alcohol by volume. There are comparatively few adulterations in beer except those mentioned. Salicylic acid is, however, frequently used as a preservative. A kind of so-called beer has been put upon the market in some prohibition localities. This often contains less than 2% of alcohol, and is sold under a variety of special names. It is frequently made in the same way as beer, and the alcohol is expelled by heat.

Saké, the favorite beverage of the Japanese, is prepared from rice fermented by the use of a peculiar fungus grown for that purpose. It contains about 12.5% of alcohol.[1]

" **Small beer**," made by the use of sugar or molasses, and yeast with some flavor, contains from 0.3% to 2% of alcohol.

[1] Church, "Food," p. 195.

Experiment 179. To show the presence of alcohol in a sample of wine, beer, or cider, heat about 100 cc. in a 500 cc. flask, into the neck of which is fitted the large end of a calcium chlorid tube. As soon as the liquid begins to boil slowly, light the vapor that escapes at the top, and observe that it burns with a characteristic alcohol flame.

Experiment 180. Collect some of the distillate from a sample of malt or fermented liquor, by boiling it very gently in a 500 cc. flask, to which is fitted, by a perforated cork, a glass tube about 60 cm. long, bent at an acute angle above the cork. At the other end of the glass tube place a small flask or test tube surrounded by cold water. The alcohol will condense in the cooled flask.

Experiment 181. Test some of the alcohol, first by taste, second, by burning, third, by adding to a sample about 1 g. solid NaOH and a few crystals of iodin. The formation of a yellowish crystalline precipitate of iodoform, CHI_3, which has a characteristic odor, indicates the presence of alcohol in the distillate.

DISTILLED LIQUORS

Distilled liquors, such as rum, gin, brandy, and whisky, are made from some saccharine substance like molasses, or some starchy substance like corn, rye, barley, or rice. The chemical action in the case of starch is first to change the starch by the addition of ground malt to sugar, which is then decomposed in the process of fermentation with yeast, into alcohol and carbon dioxid. Diastase, which is present in the malt, is the active agent in transforming the starch to sugar. This sugar is principally maltose, mixed with one of the dextrins.[1] After fermentation the alcohol is distilled off, and with it some other volatile substances, especially ethers, which give the characteristic odor and taste to the liquor.

[1] Jago, "The Science and Art of Bread Making," p. 126.

Originally the liquid actually distilled over was used directly as a beverage. This was about of proof strength, and had the characteristic flavor of the substance from which it was distilled. Practically, at the present time, a large proportion of the liquor on the market is made by the rectifiers, using as a basis pure alcohol and "high wines," which are diluted, colored, and flavored to imitate the required beverage.

The method used in making alcohol is to prepare what is called the mash by crushing the grain and other starchy material into a fine pulp, and soaking it with water, cooling it quickly, and allowing it to ferment with yeast. Sometimes the mash is made by the use of sulfuric acid, thus converting the starch directly into dextrin. The mash, after fermentation, is distilled in an apparatus so arranged that the alcohol, as it is volatilized, shall be quickly cooled and condensed in a coiled pipe. Theoretically, —

100 parts of starch yield 56.78 parts of alcohol,
100 parts of cane sugar yield 53.08 parts of alcohol,
100 parts of dextrin yield 51.01 parts of alcohol,

but practically this output is not reached.

The last part of the distillate usually contains more of the higher alcohols of the series, especially amyl alcohol, which is one of the constituents of "fusel oil." This is considered one of the most injurious ingredients in ordinary liquors.

Brandy should be made by the distillation of wine, and should obtain its odor and flavor from the fermented juice of the grape. In actual practice in the hands of the rectifier, it is often made from alcohol diluted, colored with caramel, and flavored with oil of cognac, which is distilled from the marc or refuse from the manufacture of wine. The flavor of brandy is much

improved by age, but many processes of artificial aging have been devised.

Whisky, as originally made from corn, barley, or potatoes, had a brownish color, and a peaty or smoky flavor that was imparted to it by the smoke of the peat fires used in its manufacture in Scotland and Ireland. This flavor is now imparted to the commercial article by the use of creosote or some similar compound.

Rum was originally made in the West Indies from residue left after the manufacture of cane sugar or from molasses, and the peculiar flavor it possessed was produced by the volatile oils that are developed in the manufacture of sugar from cane juice. Much of it is now manufactured by the " rectifier " in the ways already described.

Gin was originally made by the distillation of an alcoholic liquid with juniper berries, but at present the rectifier adds to the diluted alcohol, oil of juniper or turpentine, or both, some aromatic seeds and fruits, and redistills the mixture. Many roots and drugs are frequently added to improve the flavor of gin.

Experiment 182. Alcohol may be made from the fermentation of a saccharine liquid, as follows: In a 2-liter flask mix 60 cc. of molasses with 700 cc. of water, and add a small amount of yeast, and set aside in a warm place for a day or two. When the mass foams and carbon dioxid is freely given off, distill slowly by attaching a condenser, or a cork, through which passes a long tube bent to an acute angle, as in Experiment 180. Examine the distillate by taste and smell, and by the test mentioned in Experiment 181.

ADULTERATION OF LIQUORS

The most prevalent form of sophistication with brandy, rum, and gin is the artificial imitations, and the direct addition of substances injurious to health is of infrequent

occurrence. The most dangerous ingredient in the fictitious product is supposed to be the fusel oil, which is a mixture of the higher alcohols, but some authorities have made experiments with this substance, and find no injurious effect, even when considerable quantities mixed with whisky are taken for quite a length of time. It is suggested that perhaps the compounds which make some spirits, especially those which are recently distilled, or "raw," more injurious than those which are "aged," may be other by-products of fermentation, such as furfurol.

LIQUEURS OR CORDIALS

These beverages consist of very strong alcohol, flavored with aromatic substances, and often highly colored with a coal tar or a vegetable coloring matter. Absinthe, the most important of these, is yellowish green in color, and contains oil of wormwood, a substance that has a very injurious effect on the nervous system, with anise, sweet flag, cloves, angelica, and peppermint. This liqueur usually contains over 50% of alcohol.

Other beverages of this class are maraschino, distilled originally from the sour Italian cherry; chartreuse and bénédictine, named from the monasteries where they were originally made; kümmel; curaçao, made from the rind of bitter oranges; ratafia, made in France from fruits; angostura and vermuth. Nearly all these contain a large amount of sugar and a high per cent of alcohol, and are flavored with various essential oils, herbs, and spices.

PHYSIOLOGICAL ACTION OF ALCOHOL

The question as to whether alcohol is, properly speaking, a food, or whether it simply acts as a stimulating beverage,

is one that has occasioned a vast amount of discussion. The best authorities seem to agree that there are cases of disease in which it is the most useful material that can be administered. Professor Atwater, who has investigated the action of alcohol in his respiration calorimeter, speaking of its use in disease, says: "What is wanted is a material which will not have to be digested and can be easily absorbed, is readily oxidized, and will supply the requisite energy. I know of no other material which would seem to meet these requirements so naturally and so fully as alcohol. It does not require digestion, is absorbed by the stomach and presumably by the intestines, with great ease. Outside the body it is oxidized very readily, within the body it appears to be quickly burned, and it supplies a large amount of energy." From one fifth to one seventh of the total calories of the diet may be replaced by alcohol.

The same author says of the results of his experiments, that he found that "the alcohol was almost completely oxidized. The kinetic energy resulting from that oxidation agrees very closely with the potential energy of the same amount of alcohol as measured by its heat of combustion as determined by the bomb calorimeter, and the alcohol served to protect body protein and fat from oxidation." Alcohol is inferior to carbohydrates, however, to protect protein of the body from oxidation.[1] As a stimulant, alcohol acts primarily upon the nervous system and the circulation, and quickens the transmission and enhances the effect of nerve currents. Although alcohol tends to remove muscular fatigue and to increase the force of muscular action, yet its use is absolutely forbidden to

[1] See also "Food in Health and Disease," Davis, 2d edition, p. 135. Thompson, "Practical Dietetics," p. 229.

athletes in training, and soldiers in the army continue in better health if they entirely abstain from the use of this substance.

It will be seen that although alcohol has some right to be regarded as food, yet it is not a food of any practical importance, for it can merely replace a certain amount of the fat, and perhaps of the carbohydrates, in the body, while its secondary effects on the nervous and vascular systems counteract, to a large extent, the benefits derived from the production of heat and energy by its oxidation.[1]

[1] Hutchison, "Food and Dietetics."

CHAPTER XXVI

FOOD ACCESSORIES

A LARGE number of aromatic substances, which have no direct food value, are prized for the agreeable flavor which they impart to food. Condiments are by some writers defined as the substances eaten with meat and used with salt, while the term spices is restricted to those substances which are used with sugar. It is, however, impossible to draw a definite line between the two classes of substances.

The spices, since they are used only in small quantities and are quite expensive, readily lend themselves to all kinds of falsification and adulteration.

The adulterants are usually of a harmless character, and consist of English walnut shells, Brazil nut shells, almond shells, cocoanut shells, date stones, sawdust, linseed meal, cocoa shells, red sandalwood, Egyptian corn, rice flour, ground crackers, or "hard tack," bran, and many other by-products from milling, plaster, corn meal, turmeric, cottonseed meal, olive stones, and pea meal.[1]

Since the better enforcement of the Pure Food Laws by Federal and State Authorities the adulteration of spices has been almost eliminated.

In most cases these fraudulent mixtures can be detected only by the skilled chemist or microscopist, so the only safeguard of the housekeeper is to buy of reliable dealers, get the goods in sealed packages, and to pay a fair price.

[1] Rep. Conn. Agric. Exp. Station, 1898–1904.

In most cases it is safer to buy the unground spice. A brief account only of the source and properties of the most important products will be given.

Cloves are the dried flower buds of a plant belonging to the Myrtle family, growing in Ceylon, Brazil, India, the East Indies, and Zanzibar. The tree, which is an evergreen, is usually less than 40 ft. high. After the buds are picked they are laid in the sun to dry. The volatile oil of cloves, which may be distilled off with water, contains about 70% of eugenol, $C_{10}H_{12}O_2$. In addition to the use of the clove "stock" above mentioned, "exhausted" cloves, both whole and powdered, — that is, those which have been deprived of a portion of their volatile oil, — are put upon the market and mixed with fresh cloves, so that the fraud shall be less apparent.

Experiment 183. Grind about 15 grams of cloves in a porcelain mortar and introduce into a liter retort with water and boil for some time, condensing the steam in a flask floating in a pan of water. Pour the distillate into a tall tube and allow it to stand, and the oil of cloves will rise to the surface.

Cinnamon is the inner bark of a tree of the Laurel family, which is cultivated in Ceylon, Java, Sumatra, and adjacent countries. A cheaper and more common cassia which is also commercially known as cinnamon, comes from another tree of the Laurel family, which grows in China and India. Cassia buds, the dried flower of the China cassia, are also upon the market. The odor of cinnamon is due to the presence of a volatile oil, which consists principally of cinnamic aldehyde, $C_6H_5CH:CH.CHO$. A "stock" colored with red sandalwood is commonly used as an adulterant; this stock frequently consists largely of foreign barks, such as that of the elm.

Pepper is the dried berry of the *Piper nigrum*, a climbing plant which grows in tropical countries. For preparing black pepper the unripe fruit is dried in the sun, but to prepare the white pepper the ripe fruit is soaked in water and the skins are removed by friction. The taste and odor of pepper is due to the presence of an essential oil, a hydrocarbon, having the formula $C_{10}H_{18}$, and another important substance called piperin, $C_{17}H_{19}NO_3$. In addition to the ordinary adulterants in ground pepper, Egyptian corn and " long pepper " are used, while cayenne pepper is often added to raise the pungency nearer to that of the pure product.

Ginger is the rhizome of the *Zingiber officinale*, an annual herb which is a native of India and China, and is cultivated in the West Indies, Africa, and Australia. Black ginger is prepared by scalding the freshly dug root, and drying immediately. White, or " scraped," ginger is the same material that has been scraped and sometimes further whitened by treatment with some bleaching agent. Preserved ginger is prepared by boiling the root and curing with sugar. A volatile oil and a pungent resin give to ginger its characteristic odor and taste. Ginger is often adulterated by mixing with it ginger roots that have been exhausted with alcohol. The alcoholic extract or water extract is used for the manufacture of ginger ale.

Nutmeg and mace occur in the fruit of trees of the Myristica family, which grow especially in the Malay Peninsula. The tree grows from 20 to 30 ft. high, and produces flowers after about the eighth year. The fruit is surrounded by a fleshy crimson covering, which when dried furnishes the mace of commerce, and the hard seed the nutmeg. This is further prepared by washing with milk of lime. Nutmegs contain from 3 to 5% of a volatile oil. As the whole nut-

meg is used by the cook, rather than a ground product, there is not much opportunity for adulteration. Mace has the usual adulterants, and frequently a wild mace, known as Bombay mace, which is practically without taste is added.

White mustard is the seed of the *Sinapis alba*, and black mustard that of the *Sinapis nigra*. The plant, which is an herb, having yellow flowers, grows both in the United States and in Europe. Both varieties contain about 35% of a fixed oil, which can be separated by heat and pressure, a soluble ferment called myrosin, and sulfocyanate of sinapin, $C_{16}H_{23}NO_5$. The black mustard contains potassium myronate, which, when moistened with water, forms the volatile oil of black mustard, known to the chemist as *allyl isothyocyanate*, C_3H_5CSN. This has a strong mustard-like odor, and the vapor excites tears. This oil produces blisters on the skin, and hence the use of the so-called "mustard plaster." The chief adulterants of ground mustard are wheat, flour or starch, mustard hulls, and turmeric to restore the yellow color lost by the adulteration with a starch powder. Sometimes cayenne pepper is also added to restore the pungency.

VINEGAR

Since most of the vinegar of commerce is used in connection with spices and in the preparation of pickles, etc., its properties may be studied in this connection. Vinegar is dilute acetic acid, $C_2H_4O_2$, flavored with the fruit ethers, and can be made from any dilute alcoholic liquor. The whole process of the conversion of cane sugar to vinegar would be represented by the equations, —

$$\underset{\text{Cane Sugar}}{C_{12}H_{22}O_{11}} + H_2O = 2\ \underset{\text{Invert Sugar}}{C_6H_{12}O_6};$$

$$C_6H_{12}O_6 = 2\ C_2H_5OH + 2\ CO_2;$$
(Alcohol)

$$C_2H_5OH + O = C_2H_4O + H_2O;$$
(Aldehyde)

$$C_2H_4O + O = C_2H_4O_2.$$
(Acetic Acid)

The change from alcohol to vinegar is brought about by the ferment *mycoderma aceti*, found in the " mother." The conditions for this fermentation are an alcoholic liquid containing not over 12% of alcohol, an abundance of air, a temperature of from 20° to 35° C., and the presence of the ferment.

The materials used are (1) wine; (2) other fermented fruit juices; (3) spirits like diluted whisky, or residues from the manufacture of sugar; (4) malt wort, or beer; (5) sugar beets. There are several processes used for the manufacture of vinegar on a large scale, in addition to the usual process of allowing the cider to ferment in an ordinary barrel in a warm cellar with the bunghole left open for two or three years. From 100 lb. of apples the ordinary yield is 7 gallons of cider.

QUICK PROCESS VINEGAR

In France and Germany vinegar is made from wine by pouring it from time to time into an oaken vessel which has been soaked with boiling vinegar, and then siphoning off into storage tanks. The " mother casks " are used for a long time, until they contain a large amount of argols, ferment, etc.

Another method is by the " quick vinegar process," which was introduced by Schutzenbach in 1823, and is quite extensively used for spirit vinegar in Germany and the United States, and for malt vinegar in England.

In this process, an upright cask about 10 ft. high, and provided with a perforated false bottom about a foot above the true bottom, is filled with beech or oak shavings. Just under the false bottom a series of holes slanting downward is bored entirely around the cask. The shavings are soaked in warm vinegar, and covered by a wooden disk perforated with numerous holes, through which cords are loosely drawn. There are also several glass tubes extending through this disk to assist in the circulation of the air. After covering the cask with a wooden cover having a hole in the center, the dilute alcoholic liquor is poured into the upper compartment and slowly trickles over the shavings.

As the process of oxidation proceeds, considerable heat is developed, and this causes an upward current of air which enters the cask below the false bottom, and escapes to the upper part through the glass tubes. By a siphon the partially acetified liquid is drawn off into a second cask. With 4 % of alcohol in the original liquid, good vinegar will be drawn from the second vat. If " vinegar eels " appear, the converting cask is treated with vinegar so hot that when drawn out it has a temperature of 50° C., which kills the eels. When spirit is used in this process, a little infusion of malt is added to furnish organic matter sufficient for the growth of the ferment.

Wine vinegar may be red or yellowish in color, and contains from 6 to 9 % of absolute acetic acid. Beer and malt vinegars are higher in specific gravity than wine vinegar, and contain considerable extractive matter, and from 3 to 6 % of acetic acid. Cider vinegar has the odor of apples, and when evaporated yields an extract that smells and tastes like baked apples. It contains malic acid and from $3\frac{1}{2}$ to 6 % of acetic acid. The acidity should never

be below 4 % and the specific gravity should never be less than 1.015. The strength of vinegar is often estimated in "grains"; thus a "40 grain" vinegar would contain 4 per cent of acetic acid.

Imitation vinegars are sometimes made by the use of acetic acid distilled from wood, and flavored with acetic ether and colored with caramel. The extract from this imitation vinegar differs from malt vinegar in not containing phosphate, and from wine vinegar in the absence of tartaric acid, and from cider vinegar in the absence of malic acid.

The acidity of vinegar assists in the softening of some foods, such as beets, cabbage, cucumbers, hard-boiled eggs, corned beef, and lobsters, but it should not be used in excess on account of its tendency to cause anemia and emaciation.

Experiment 184. The approximate acidity of a sample of vinegar may be ascertained by the use of saturated limewater. This is made by allowing water to stand for some time with frequent shaking over slaked lime. The strength of the clear liquid which is drawn off is very nearly $\frac{1}{21.4}$ normal. To test the vinegar, 2.75 cc. are placed in a small Erlenmeyer flask with some water, and a few drops of phenolphthalein as an indicator, and titrated with limewater contained in a burette. When the pinkish color shows that the free acid has been neutralized, read the number of cubic centimeters of limewater used, and divide this by 10. This gives the percentage of acid in the vinegar.

Experiment 185. To detect a free mineral acid in vinegar, add to 5 cc. of vinegar 5 or 10 cc. of water; after mixing well, add 4 or 5 drops of an aqueous solution of methyl-violet (one part of methyl-violet 2 B in 10,000 parts of water). The occurrence of a blue or green color indicates a mineral acid.[1]

[1] Bul. 65, U. S. Dept. Agric., Bu. Chem., p. 64.

Experiment 186. Caramel is often used to color imitation vinegars. To detect this, place about 25 cc. of the sample in a large test tube or in a bottle, and add to it about 10 grams of fuller's earth, shake the sample vigorously for several minutes, and filter. The first portion of the liquid which passes through the filter should be filtered again. Return the filtered sample to original tube, and compare the color of this solution in a similar tube with that of an equal quantity of vinegar that has not been treated. If the treated sample is considerably lighter in color than that which has not been treated, the vinegar is probably colored with caramel. Caramel occurs naturally in malt vinegar.[1]

Experiment 187. To obtain the acetic acid of vinegar free from extractive matter, pour 250 cc. of vinegar into a flask, add to it 25 cc. of dilute sulfuric acid, and distill by the use of the simple apparatus described in Experiment 180. Collect the distillate in a flask and examine its odor, taste, etc.

SALT

Common salt, NaCl, has been used for thousands of years as an essential ingredient of foods, and as a preservative. Fortunately, it is found in numerous localities all over the world. In the United States, the chief salt-producing localities are Michigan, New York, Kansas, Louisiana, and Ohio, which together furnish about 90 % of the total output,[2] and smaller quantities are obtained from California, Utah, West Virginia, Oklahoma, Texas, and Pennsylvania.

Salt is obtained either as rock salt, which is mined in several localities, by the evaporation of sea water or that of salt lakes, or by the evaporation of brine, which is obtained from salt wells or borings into the salt bed. Most of the table salt of commerce is made by the latter process.

[1] Bul. 100, U. S. Dept. Agric., Bu. Chem., p. 48.

[2] Bailey, International Congress of Applied Chemistry, Berlin, 1903.

In some localities solar evaporation is relied upon for concentration of the brine, but usually the brine is heated in an open pan by direct heat or in a " Grainer " by steam heat. Many producers are introducing cement evaporating pans, automatic self-acting rakers, and vacuum pans.

The brine when pumped from the wells contains some impurities, and these, especially the calcium sulfate, are deposited when the brine is first concentrated, so that in this way the brine can be partially purified in the first pan, before it is run into the evaporating pans proper. The composition of a good brand of salt is as follows: —

	Per Cent
Sodium chlorid	97.75
Insoluble residue	.03
Calcium sulfate	1.84
Magnesium chlorid	.38
Total	100.00

Most of the salts on the market contain from 97 to 99 % of pure salt. When salt absorbs moisture, it becomes hard and inconvenient for domestic use. This is sometimes remedied by the addition of a small quantity of starch or magnesium carbonate.

CHAPTER XXVII

PRESERVATION OF FOOD

It is only within the last hundred years that any adequate methods for the preservation of food have been devised; in fact, within the last fifty years the greatest advances have been made in this art. Formerly, fruits, vegetables, and meats must be consumed in the locality where they were produced, and fruits especially must be used as soon as ripe. In 1804 M. Appert of Paris found that meat and other organic substances would keep indefinitely if sealed and then heated in boiling water. In 1810 he suggested the method of introducing steam and heating, and then sealing, so that when the vessel cooled a vacuum was formed.

By the use of modern methods of preservation the season for the use of each fruit has been extended; and the product of one climate can be transported to another climate for consumption. Meats and vegetables can be preserved for months, and so the variety of food for man has been greatly increased. Since the fermentative changes that take place when food is kept for some time are due to the growth of various microörganisms, any process which will prevent this growth or keep these organisms out of the food will assist in its preservation. Warmth, moisture, and access of germ-laden air are conditions favorable for the decomposition of food.

Some of the methods adopted for the preservation of

food are (1) maintaining a low temperature; (2) drying so as to remove as much moisture as possible; (3) addition of sugar or glucose; (4) the use of saltpeter or brine; (5) pickling with vinegar; (6) canning or placing in a sterilized atmosphere; (7) the use of chemical preservatives.

Fermentation and decay take place best at a moderately high temperature, so cold storage is introduced not only to transport fruits and meats from one section of the country to another, but also to keep the food from the season when it is abundant until the season when it is scarce. Preservation by the use of salt, smoke, sugar, saltpeter, or vinegar furnishes conditions unfavorable to the growth of microorganisms, and so decay is prevented. Dried or " jerked " meat will keep a long time for the same reason, especially in a dry climate.

In smoking the meat, which is usually previously salted, it is dried and penetrated by acetic acid, creosote, and other preservatives of the smoke.

In " quick smoking " processes the meat is dipped several times in a solution of pyroligneous acid (which is made by the distillation of wood) and dried in the air. Other chemicals are frequently used.

The process of food preservation by canning or protecting from air and sterilizing has developed to an enormous extent in the United States. When we consider the annual output of 238,000,000 cans of corn, 212,000,000 cans of peas, and 388,000,000 cans of tomatoes, besides millions of cans of other vegetables and fruits, some idea of the value of this process to the human race is obtained.

Fortunately, too, most of this food is prepared in such a way as to be entirely wholesome. The object to be attained in canning is to destroy the microorganisms of various kinds, so it makes no special differ-

ence whether a little air remains in the can or not, as long as the contents is perfectly sterilized, although formerly it was held that all the air must be excluded.

In domestic practice, fruit may be preserved by packing in glass cans, filling nearly full of water, adding some sugar if desired, and then immersing the cans nearly to the neck in a vessel of cold water. The water is heated to boiling, and allow to boil from 15 to 30 min., dependent on the size of the fruit, and then the cans are removed from the water and immediately sealed. This process has the advantage of preserving the fruit whole and unbroken.

Another method much in vogue is to cook the fruit or vegetables, then put them, while still hot, in glass or tin cans that have just been taken out of boiling water, and to seal immediately with the ordinary glass cover and rubber washer or with cork and sealing wax.

The method used at canning factories is, in general, to pack the material in tin cans, with the required amount of water, and after sealing to cook with hot water or steam. The cans are then punctured to allow the excess of air to escape, again sealed with a drop of solder, and again heated for some time to destroy all microörganisms.

A more modern method of canning is to cook the fruit at a temperature of 82° to 88° C. before transferring to the cans, and afterward heat in the cans, when sealed, to a temperature of about 125° C. in dry air retorts, so that it shall be completely sterilized.[1] This process can be finished in a shorter time than the former, and on account of the higher temperature employed is very effective.

Experiment 188. To show the effect of exclusion of ordinary air from fruit, prepare two samples thus: Place some hot apple sauce in two 250 cc. bottles that have just been heated

[1] "Food Inspection and Analysis," Leach, 3d ed., p. 901.

with boiling water. In the mouth of one bottle place a perforated cork, through the opening of which passes a calcium chlorid tube packed with cotton, that has been heated in an oven to 120° C. In the mouth of the other bottle place a cork having a small opening in it. Allow these bottles to stand for a week or more in a warm place, and notice the almost entire absence of mold in the bottle which is protected from the microorganisms of the air by the cotton, and the abundant mold on the surface of the sauce in the other bottle.

When canned food spoils if put up in tin cans, the can usually becomes convex on the ends, instead of concave, as it is found normally, on account of the generation of gases by fermentation. Formerly it was not an uncommon practice for manufacturers to puncture these "swells" and reheat them to stop fermentation, and afterward solder them again, and put them on the market.

Since tin cans are used in the preservation of food, and as the tin plate, from which the cans are made, often contains considerable lead, it is not uncommon to find salts of tin, iron, and lead in the canned products. This is partly due to carelessness in soldering of the cans, and allowing the drops of the solder, which may contain 50% of lead, to remain inside the can, and partly because the acid fruits act on the tin plate of which the can is composed.

Formerly very grave danger was apprehended from the metals that might be contained in canned goods, but the fact is that we have not experimentally proven whether the small quantities that are found have a poisonous effect or not.

Experiment 189. To show the presence of iron in canned fruit, test some of the juice from a "swell" can of California grapes or other fruit (better one that has been canned for some time) with a little of a strong infusion of tea. Since the tea

contains tannic acid (Experiment 172) it will form a black coloration (ink) with the iron that has been dissolved from the tin plate by the acid of the fruit.

CHEMICAL PRESERVATIVES

In recent years the practice of adding preservatives to food has greatly increased. These preserve the foods by preventing the growth of bacteria. There may be a difference of opinion in regard to the use of *some* of them, but it seems perfectly reasonable that antiseptic substances which will prevent the decay of food will be liable also to retard the digestive processes. Food that has really begun to decay may, it is by some asserted, by the use of these preservatives, be put on the market and sold as wholesome. It is no defense of the practice to claim that food that has been thus treated is better than if it had not been treated, for such food, which has begun to decay or ferment, should be condemned without question.

When preservatives are added to food intended for the use of invalids and young children, they are especially liable to interfere with the digestion and prove injurious to the system. Many tests have been made upon the lower animals, and some results have been obtained which indicate that some preservatives may be used with impunity, but the time has not come to admit the use of preservatives in foods without question. This position has been taken by the health authorities in many states; and where the use of these substances is not actually prohibited, they require at least that each package so preserved shall be labeled to that effect.

Dr. Vaughan[1] says, "A true food preservative must keep the substance to which it is added in a wholesome

[1] *Jour. Am. Med. Assoc.*, Vol. XLIV, p. 753.

condition so that it can be consumed by persons in every physical condition of life without impairment of health or danger of life. It is not the function of a food preservative to impart to the food a deceptive appearance and to make it look better than it actually is. The law . . . forbids the use of all meat preservatives that restore the color and fresh appearance to partially decomposed meats. . . . To prevent the development of those bacteria that produce odoriferous substances while the more toxic bacteria, that develop no telltale odor, continue to grow and multiply, does not comply with the requirements demanded by a food preservative that asks for legal sanction. . . . To retard the multiplication of the lactic acid bacillus, and thus prevent the souring of milk, while colon bacilli continue to multiply uninterruptedly is not the function of a true food preservative. . . . The man who adds formaldehyde to his milk takes down the danger signal, but does not remove the danger."

In regard to the action of preservatives on the digestive fluids, it should not be forgotten that preservatives if permitted in the food are liable to be taken by persons with every degree of digestive impairment. The free hydrochloric acid of the gastric juice will be neutralized by sodium sulfite, if this salt is used as a preservative, and this cannot fail to interfere seriously with the action of the digestive enzymes. It seems to be well established that formaldehyde also interferes with their action. In regard to some of the other preservatives, sufficient experiments have not been made to prove definitely that they interfere with the digestive functions.

The author above quoted believes that a food preservative in order to receive legal sanction should keep the food in a wholesome condition and not simply retain this

appearance while bacterial changes continue; in the largest quantities used it should not impair any of the digestive processes; and finally this substance must not be a cell poison, or, if it is a cell poison, it must be added to foods only by persons who have special training, and not by a manufacturer who has no knowledge of the subject. Foods containing these preservative substances should also be plainly marked, so that the presence of the preservative can be known to the consumer.

"If the use of any preservatives is to be permitted in food, boric acid and sodium benzoate are the least objectionable, since they appear to have less tendency to disturb the digestive functions than have the others." [1]

At the conclusion of an exhaustive series of experiments upon the effect of boric acid and borax on the general health, Dr. H. W. Wiley says: "It appears, therefore, that both boric acid and borax when continuously given in small doses for a long period, or when given in large quantities for a short period, create disturbance of appetite, of digestion, and of health." [2]

Some of the preservatives most used are borax ($Na_2B_4O_7$, $10\,H_2O$), boric acid (H_3BO_3), salicylic acid ($HC_7H_5O_3$), ammonium fluorid (NH_4F), benzoic acid ($HC_7H_5O_2$), sodium benzoate ($NaC_7H_5O_2$), formaldehyde (HCHO), sodium sulfite (Na_2SO_3) and sulfurous acid (H_2SO_3), beta-naphthol ($C_{10}H_7OH$), abrastol $Ca(C_{10}H_6SO_3OH)_2$, and saccharin ($C_6H_4COSO_2NH$). The detection of small quantities of these substances in food usually requires the service of an experienced analyst.

Borax and boric acid are often sold under various names,

[1] H. Leffman, Jour. Franklin Inst. 147 (2), 97–109.

[2] Circ. 15 or Bul. 84, U. S. Dept. Agric., Bu. Chem. See also "Food Inspection and Analysis," Leach, 3d ed., pp. 821–822.

such as " Preservaline," and mixtures of borax with other preservatives are also on the market under various trade names. This preservative is used especially in milk and meat products. The method of detection given under Milk, Experiment 166, should be followed.

Salicylic acid is a white crystalline powder, very soluble in alcohol, and soluble in 500 parts of water. It is used in preserving fruit products, beer, cider, milk, etc.

Experiment 190. To test for salicylic acid, to 50 cc. of the substance to be tested, made feebly acid with a few drops of sulfuric acid, add an equal bulk of a mixture of equal parts of ether and petroleum spirit, and shake vigorously. Allow the liquids to separate, and draw off the solvent, and allow it to evaporate at a gentle heat. If salicylic acid is present, fine silky crystals will usually be seen. Add to the residue left on evaporation a few drops of water and a drop of very dilute ferric chlorid or of ammonium ferric alum solution, and if there is any salicylic acid, a characteristic violet color is produced.

Sodium benzoate, which is more frequently used as a preservative than benzoic acid, is a white granular powder, of a slightly aromatic odor, and disagreeable taste. It is readily soluble in water, and the solution is used as a preservative, especially for catsup, mince meat, jams, and jellies.

Experiment 191. Benzoic acid or a benzoate may be detected in the absence of salicylic acid by Peter's method,[1] which depends on oxidation of the benzoic acid to salicylic acid by treatment with sulfuric acid and barium peroxid, and then applying the ferric chlorid test for salicylic acid noted in Experiment 190.

Sodium sulfite is a white solid readily soluble in water. It has the characteristic taste of the smoke of a burning sulfur match.

[1] Bul. 65, p. 160, U. S. Dept. Agric., Bu. Chem.

The sulfites are used especially to preserve meat and meat products, and give them a " natural " red color, and for alcoholic beverages, cider, fruit juices, and catsup.

Experiment 192. As the test for the detection of sulfurous acid depends on converting it into sulfuric acid, the following method may be used: Place 200 g. of the suspected food, which, if solid, should be ground with water in a mortar, in a flask, make acid with phosphoric acid, connect with a condenser, and distill slowly, till 20 cc. have come over. Boil this distillate in a large test tube or small flask with bromin water and add a few drops of barium chlorid. The formation of a white precipitate of barium sulfate indicates that a sulfite was present.

Formaldehyde is a gas that readily dissolves in water. The 40% solution is usually sold under the name of "formalin." The gas has a characteristic odor. It is used as a preservative for fish, broken eggs, meat products, milk, etc. The method of testing for formaldehyde is given under Milk, Experiment 167.

Experiment 193. To some egg-white, in a porcelain evaporating dish, add a moderate quantity of formaldehyde. Place the dish over a water bath, and warm, not above 60° C., for some time.

Saccharin acts slightly as a preservative, but more especially as a sweetening agent. It is a white crystalline powder, soluble in 1000 parts of cold water, and has about 500 times the sweetening power of cane sugar. At present it is not extensively used, except in some cases in soft drinks. In many states its use is forbidden by law on the ground that it takes the place of sugar, which is a valuable nutrient and that it may have an injurious effect on the system if taken continuously.

Experiment 194. For the detection of saccharin in jelly, preserves, or canned vegetables, use about 20 grams of the sam-

ple. Grind this in a mortar with about 40 cc. of water, strain through muslin, acidify with 2 cc. of dilute sulfuric acid, and shake moderately with ether. Separate the ethereal layer and allow this to evaporate spontaneously in a watch glass, and take up the residue with water. If saccharin is present, this solution will have a sweet taste. To confirm this test add one or two grams of sodium hydroxid, place the dish in an oil bath and heat to 250° C., for twenty minutes. This will convert the saccharin into salicylic acid. After cooling and acidifying with sulfuric acid, extract as usual and test for salicylic acid according to Experiment 190.[1]

COLORING OF FOOD PRODUCTS

This is another method of falsifying food, and making it appear better than it is, or of simulating wholesome foods with a combination of entirely foreign substances. The coal-tar colors, of which there is an endless variety, lend themselves very readily to the coloring of foods and beverages. The use of these dyestuffs is not only liable to lead to injury of the health of the consumer from the poisonous nature of the coloring material, but the consumer is deceived so that he buys the goods thinking they are of greater value than they actually are. There are some of the coal-tar or aniline colors which are of themselves harmless, but in the process of manufacture some poisonous substance such as arsenic or mercury is used, and a little of this remains in the finished product, making it dangerous for consumption. It is true that so far as we know the coal-tar colors are mostly harmless, so the chief cause for objection to their use is on account of the fraud on the consumer. The United States Department of Agriculture, after a careful examination, has approved of the use of eight aniline colors which are known as "certified dyes." These

[1] Bul. 65, p. 51, U. S. Dept. Agric., Bu. Chem.

only should be used in foods. In some cases vegetable colors, such as turmeric, logwood, annatto, Brazil wood, beets, and safflower are used. The only animal coloring matter in common use is that of the cochineal, called carmine red.

Experiment 195. Test a sample of tomato catsup for a coal-tar dye by the method described in Experiment 147.

Salts of copper are sometimes used to impart an artificial green color to canned goods, particularly peas, beans, brussels sprouts, and pickles. An old-fashioned method for greening pickles was to put a copper cent in the vinegar in which they were boiled. The practice of coloring food material by the use of compounds of copper is more common on the Continent than in the United States. Imported goods frequently contain considerable copper.[1] Examinations of a large number of canned vegetables greened by copper, as bought in Massachusetts, showed them to contain from a trace to 2.75 g. per can, calculated as copper sulfate. The author has found in an ordinary pickled cucumber the equivalent of one seventh of a grain of copper sulfate.

Experiment 196. Incinerate fruit or vegetables in a porcelain evaporating dish with sulfuric acid, adding a little nitric acid from time to time until the carbon is completely consumed and a grayish or reddish ash is obtained. Add a few drops of hydrochloric acid to the ash, filter into a small test tube, and add to this solution an excess of ammonium hydroxid, when a blue color indicates the presence of copper.

[1] Leach, "Food Inspection and Analysis," p. 909.

CHAPTER XXVIII

ECONOMY IN PREPARATION OF FOOD; DIETARIES

The importance of cooking food has already been discussed (p. 165). It is owing to the practice of cooking food that the dietary of civilized man has been greatly enlarged and improved. Many kinds of food which would be not only unpalatable, but indigestible, in the raw state are rendered wholesome and nourishing by some process of cooking. So the proper cooking of food may be regarded as an art; indeed, one distinction of a civilized man is that he is one who prepares his food by cooking. Most foods, with the exception of fruits, require cooking; animal foods especially are cooked to make them palatable and wholesome.

In addition to what has been said on previous pages about cooking in the case of individual foods, since all the different foods have now been studied, some general statements will be more readily understood.

DIGESTION OF STARCH

In the cooking of starchy foods it will be noticed that the starch grains, as " put up," so to speak, by nature, are very close and compact in most seeds, so that they will withstand any natural temperature, and a moist as well as a dry climate. When these seeds are to be used for food, they must be soaked with water and allowed to swell.

By this treatment the fine particles of starchy substances will be in a much better condition to be attacked in the process of digestion by the alimentary liquids. The starch grains are rendered much more digestible by being cooked. The food should be thoroughly mixed with the saliva so that the *ptyalin*, the digestive ferment which it contains, may readily act on the starch, thus splitting it up into various dextrins and finally into maltose, the end product of its digestion. These changes, however, are only begun in the mouth, and take place best in an alkaline medium.[1] After about half an hour the acid fluids of the stomach tend to check the salivary digestion, and the food passes on into the duodenum before all the starches are changed to maltose.

DIGESTION OF FATS

Fats undergo a kind of combustion in the body and are changed to carbon dioxid and water, thus furnishing much of the heat needed by the body. If these are too expensive, their place may, to a considerable extent, be taken by the carbohydrates. In any case the excess, or that which remains over what is actually used up in doing the work required of the body, is stored up, and may be drawn upon as a reserve. Fats and oils are modified by digestion and prepared for absorption mostly in the intestines.

The fats should be taken into the system as fats and not as products of the destruction of fats. In the process of digestion in the intestine, the fat is subjected to a double process of emulsification and saponification, which is brought about by the combined action of the bile and the pancreatic juice. This process is interfered with,

[1] "Food in Health and Disease," Davis, p. 29.

and indigestion is produced when overheated fats are taken into the system. These volatile products which are produced by the decomposition of the fats cause the familiar irritation of the eyes, and a disagreeable odor, when food is fried.

COOKING ALBUMINOUS FOOD

In cooking an albuminous food, as an egg, if frying is the method of cooking used, the temperature is necessarily so high that the egg albumin becomes soluble with difficulty in the digestive fluids. Oysters,[1] when satisfactorily cooked, are heated only to boiling, or if fried, are surrounded by a batter, which protects the albuminous tissues from being overheated. A high temperature also greatly decreases the digestibility of the gluten of grains. It has been usually held that milk is less digestible if boiled than if simply pasteurized, but later authorities believe that the casein at least of the boiled milk is not less wholesome than that of raw milk.

Beans and peas, which contain both legumin and starch, require considerable cooking to soften the cellulose and make the starch digestible. If these vegetables are cooked in hard water, there is danger that an insoluble compound shall be formed, by the combination of the legumin with lime or magnesia in the water; steaming, as previously suggested, will partly obviate this difficulty.

COST OF FOODS

Again, in seeking for economy of food, the question arises, What food furnishes the largest amount of nutriment at the most reasonable cost? As we shall see a

[1] Richards and Elliot, "The Chemistry of Cooking and Cleaning," p. 51.

little later, the amount of energy in terms of " calories " that each food is capable of producing, has been carefully determined, and this will furnish a clew to the value of different foods. For instance, a certain sum invested in bread will yield much more energy than the same sum invested in milk or in meats. Both the latter foods are valuable, but they are not cheap.

To build up the tissues, a cheap form of protein is that contained in peas or beans, while eggs are eight times as expensive, and beef five times as expensive at ordinary prices.

VEGETABLE *VERSUS* ANIMAL FOOD

In general, vegetable food is cheaper than animal food, either as a source of energy or to build up the tissues. The reason for this is evident when we consider that the vegetable foods are built up from the simple substances found in air, water, and soil, while the food of animals consists of highly organized vegetable or animal substances. One author states, as an illustration of the comparative cost of vegetable food, that $2\frac{1}{2}$ acres devoted to raising mutton would support a man for a year, while the same amount devoted to the growing of wheat would support 16 men for the same time. It may be said that as the vegetable food is so much more bulky it would require much more heat to cook it, but with the best appliances, the cost of this additional fuel would not counterbalance the increased cost of animal food.

While carbohydrates are cheap constituents of food, proteins and fats are expensive. If the fat is derived from animal sources, this is particularly true, but foods containing cottonseed oil, and the oil of some varieties of nuts, furnish fats at a reasonable price.

ECONOMY OF FOOD

There is no necessary relation between the cost of a food and its nutritive value, for we pay for color, size, appearance, and flavor, in foods, not for their value in feeding the body. There is practically as much nourishment in the cut of beef costing 8 cents a pound as in that costing 16 cents; a fine quality of starch in the form of arrowroot or sago is expensive, but the same amount of starch of a different flavor made from corn is very cheap; a Roquefort cheese costs perhaps 75 cents a pound, while a cheese just as good for food, but made in New York State, costs only 25 cents.

METHODS OF COOKING

It is important that the right method of cooking should be selected for each food; a method that shall develop the agreeable flavors and make the food as digestible as possible. A cheap cut of beef may be made appetizing and wholesome by careful and skillful cooking, and it is equally true that an expensive cut may be made tough and tasteless by the ignorant cook. It is easy to spoil good food, and render it unwholesome by cooking it in fat, or by too slow heating. Potatoes may be cooked until they are "mealy" and the separate starch grains glisten in the light, or they may be water-soaked and waxy, and consequently slow to digest. Little skill is required to prepare sour or heavy bread, overheated toast, tough beefsteak, or muddy coffee, but the raw material costs just as much as if the food product had been made wholesome and agreeable.

ECONOMY OF FUEL

Great economy of fuel can be secured by the use of the right kind of stove or range, and by utilizing such an

appliance as a "steamer," so that half a dozen dishes can be cooked at one time over the same fire. This latter vessel is especially economical when gas, either natural or artificial, or gasoline is used for fuel. When the water is once brought to a boiling temperature in the steamer, a very small flame will keep it boiling, and the contents of the vessel will not become appreciably hotter, nor will it cook much quicker, if it boils much more tumultuously. Boiling water means 100° C., and it does not get any hotter, except under pressure. This is a fact too often forgotten by the cook, who is anxious to "hurry the dinner."

Another interesting application of science to the culinary art is the invention of the Aladdin oven, by Edward Atkinson.[1] This oven consists of a metallic chamber surrounded by non-conducting material, and so arranged that it can be heated from below with a good kerosene lamp or Rochester burner. Almost any food may be cooked in this oven, and it is especially adapted to the preparation of soups and the cooking of vegetables.

The latest advance in this line is the "fireless cooker," which is so well known that a description is unnecessary. This device also substitutes a low temperature continued for a long time for a high temperature acting only for a short time. It introduces a great opportunity to save fuel, especially in the cooking of cereals and stews.

DIETARIES

We have already discussed the two general classes of nutrients (p. 168) and to some extent the properties of each class. Most of our knowledge of the composition

[1] "The Right Application of Heat to the Conversion of Food Material," *Proc. Am. Assoc. for Adv. Science*, 1890.

and nutritive value of food has been accumulated, in the United States and Europe, within the past fifty years. Although the analysis of milk was reported by Boussingault and Le Bel in 1831,[1] yet it was not until Liebig, Playfair, Boeckman, and others, about the middle of the last century, devised new methods for the analysis of foods and feeding stuffs, that we began to have a definite knowledge of this important subject.

COMPOSITION OF FOOD MATERIALS

With the adoption of the so-called Weende method, proposed by Henneberg in 1864, new impetus was given to this branch of investigation, and numerous improvements have been made, till now chemists generally agree on the methods of analysis to be employed. American food products first began to be investigated in 1878–1881, by Professor Atwater, under the auspices of the United States Fish Commission, and these investigations have been carried on more recently by agricultural colleges, the experiment stations of the various states, and the Department of Agriculture of the Federal government. The latter department, at an expense of from $10,000 to $20,000 per year, has extended these investigations on human nutrition, until at the present time we have very complete data upon this subject.[2]

HEAT UNITS

We have already learned that the analysis of a food shows the per cent of water, proteins, fats, carbohydrates,

[1] Atwater, "Foods, Nutritive Value and Cost," Farmers' Bul. 23, U. S. Dept. Agric.

[2] Atwater and Woods, "Chem. Comp. of Am. Food Materials," Bul. 28, U. S. Dept. Agric., Office of Exp. Stations.

and mineral salts, which it contains, and each of these, with perhaps the exception of water, has its food value. In order to compare the different foods, and calculate the relative amount of energy that can be obtained from them, the ordinary method is to determine the "heat units," or "calories," that can be produced by the combustion, under standard conditions of a given amount of food. Although the results are not *exactly* the same when food is oxidized in the body to produce energy, as when it is burned in a calorimeter to produce heat, yet this method is convenient for classification and computation of the relative value of foods.

FUEL VALUE

A calorie [1] is the amount of heat that is required to raise the temperature of one kilogram of water from 0° to 1° C., or approximately the amount of heat that would be required to raise one pound of water 4° F., and is equal to 3084 foot-pounds. The "fuel value" means the total calories obtained by the combustion of any food substance within the body. Considering the ordinary food materials, the following estimate has been made from the average amount of heat and energy or the "fuel value" of each of the classes of nutrients: —

One pound of protein gives	1860 calories
One pound of fats gives	4220 calories
One pound of carbohydrates gives	1860 calories

From this it will be seen that a pound of protein of lean meat, for instance, is about equal to a pound of sugar or

[1] See "Foods, Nutritive Value and Cost," Atwater, also "Practical Dietetics," Thompson, also "Air, Water, and Food," Richards and Woodman, "Chemistry of Food and Nutrition," Sherman, and "Food in Health and Disease," Davis.

starch, in yielding heat and mechanical energy, and that fats have a fuel value about two and a quarter times that of the carbohydrates or protein.

From the analysis of foods, to which reference has been made, it is possible to calculate the fuel value of a given amount of any food or of the rations supplied to a club, family, or charitable institution.

RESPIRATION CALORIMETER

Experiments have also been carried on by W. O. Atwater, at Wesleyan University, and later by C. F. Langworthy, of the Department of Agriculture at Washington, in what is known as a "respiration calorimeter." In this apparatus, which is a small closed room, the experimenter remains for several days, and all the food, air, and water used is weighed and passed in to him, and all the products given off from the body are also weighed and analyzed. A careful record is also taken of the temperature, and if the experimenter works to exercise his muscles, a record is made of the mechanical work accomplished. "The main value of the experiments so far conducted in this calorimeter consists in the actual demonstration that the law of conservation of energy operates within the body in precisely the same manner as it does outside." In man it was found that the measured energy of the food consumed by the subject within the calorimeter was within 1% of the calculated or theoretical energy.

STANDARD DIETARIES

Having a knowledge of the composition of food, and a method for finding its value as an energy producer, we are in a position to study the food of different individuals

or classes of people, or to study dietaries. A dietary, then, would be a known amount of food of known composition, per day per person, and a standard dietary would be such a combination of materials as furnishes a sufficient amount of each of the nutrient substances to fully sustain the body. Professor Voit of Munich was one of the first to prepare standard dietaries, and his work has been supplemented by a large amount of work in the United States, especially within the last twenty years.

DIETARY STUDIES

It has been recently pointed out that there are two methods of estimating dietaries. One method is by studying the food consumption of classes of people or individuals, when they have a free choice of food, or when they procure such food as their circumstances allow them to buy. The other method contemplates the feeding to classes of individuals, or to selected persons, certain foods of known weight and composition, and studying the nitrogen balance, as it is called; that is, the amount of nitrogen taken into the body, daily, in the food, and the amount excreted. If there is more nitrogen excreted from the body than taken in, the system is evidently not fully nourished. If there is a slight excess of nitrogen maintained, the food is sufficient for the amount of work done by the individual. An excess of nitrogenous material, or of fat, may be stored in the body for use in emergencies.

Returning to the ordinary method of studying dietaries, some examples may be given of the results observed by different chemists:[1] —

[1] Chittenden, "Physiological Economy in Nutrition"; also Atwater, *loc. cit.* See also "The Principles of Human Nutrition," Jordan.

PER DAY PER MAN

	PROTEIN	FATS	CARBO-HYDRATES	FUEL VALUE	NUTRITIVE RATIO
	Lb.	Lb.	Lb.	Calories	1 to
Well-fed tailors, England, Playfair . . .	.29	.09	1.16	3055	4.7
Blacksmiths, England, Playfair	.39	.16	1.47	4115	4.7
Well-fed mechanics, Munich, Voit	.34	.12	1.06	3085	4.0
Brickmakers, Munich, diet mainly corn meal and cheese, Ranke . .	.37	.26	1.49	4540	5.6
Brickmakers, Massachusetts, very severe work	.40	.81	2.54	8850	11.0
Professional men, Middletown, Ct., Atwater	.27	.34	1.08	3925	6.6
University professors, Munich, light exercise, Ranke	.22	.22	.53	2325	4.7

In the above table the nutritive ratio, mentioned in the last column, is the ratio of the protein to the sum of all the other nutritive ingredients. The fuel value of the fats, as previously noted, is two and a quarter times that of the protein and carbohydrates, so in the calculation the quantity of fats is multiplied by two and one fourth, and the product is added to the carbohydrates. This sum divided by the weight of the protein gives the nutritive ratio. Thus, in the first dietary quoted, the ratio of protein to fats and carbohydrates is as 1 to 4.7.

Some standard dietaries have been compiled by Atwater, and represent what is believed by the several authors to be the amount needed by persons with different degrees of labor. The amounts are expressed in grams per day per individual.

	Protein	Fats	Carbohydrates	Total	Fuel Value, or Calories
Children, 6 to 15 . . .	75	43	325	443	2041
Women, at moderate work, Voit	92	44	400	536	2426
Man, at moderate work, Voit	118	56	500	674	3055
Man, at hard work, Voit	145	100	450	695	3370
Hard labor, Playfair .	185	71	568	824	3748
Man, at moderate work, Atwater	125	125	450	700	3520
Man, at hard work, Atwater	150	150	500	800	4060

Experiment 197. Study the food used by a family or club for a period of several weeks. Note the actual weight of all food purchased, the cost, and the number of individual meals taken. From the tables given by Atwater, compute the total amount of protein, fats, and carbohydrates consumed, and the amount per day per capita. By the use of the same tables estimate the "fuel value" of the food, and the nutritive ratio. Tabulate the results as in the table quoted from Mrs. Richards on page 378.

The daily amount of solid food consumed by the adult male is 50 oz. to 60 oz., and the water used is about the same. In case of severe labor this amount of food would be increased to 75 oz., the addition being mostly in fats and carbohydrates.[1] The standard ratio for health, of protein to fuel ingredients, has been placed at 1 to 5.8 by the Experiment Stations of the Department of Agriculture.

According to the standard dietaries given, and many others that might be quoted, an average man doing light work would consume 116 g. of protein, with sufficient fat and carbohydrates, to give 3050 calories; some

[1] Thompson, "Practical Dietetics," p. 20.

authorities [1] would decrease this as low as 100 g. of protein. This could be obtained from a great variety of diet, either largely vegetable, or with a moderate amount of animal food.

From some experiments by Chittenden,[2] and others, upon several groups of persons, some of whom lived sedentary lives, and others of whom were athletes and soldiers, it was shown that it was possible to maintain the nitrogen balance and remain in good health with considerably less food, especially of the protein class, than the accepted dietary standards would indicate. On a diet containing only 42 to 55 g. of protein, instead of 116 to 121, and enough carbohydrates and fats to make 1750 calories, instead of 3050, the men lived and carried on their daily work for several months.

Computations of the diet of farmers show an interesting similarity of fuel values of food in different parts of the world.[3]

Farmers in Connecticut	3,410	Calories
" " Vermont	3,635	"
" " New York	3,785	"
" " Mexico	3,435	"
" " Italy	3,565	"
" " Finland	3,474	"
Average	3,551	"

The following ideal daily ration of solid food is given by Mrs. E. H. Richards: [4] —

[1] "Chemistry of Food and Nutrition," Sherman, p. 228; also "Principles of Human Nutrition," Jordan, p. 196.

[2] "Physiological Economy in Nutrition"; "Economy in Food," *Century Magazine*, Vol. 70, p. 859.

[3] "The Fundamental Basis of Nutrition," Lusk, p. 14.

[4] "Chem. Comp. of Am. Food Materials," Bul. 28, U. S. Dept. Agric., Office of Exp. Stations. Also see Farmers' Bul. 23, U. S. Dept. Agric., "Principles of Human Nutrition," Jordan, p. 351.

Material	Amount Grams	Proteins	Fat	Carbohydrates	Calories
Bread	453.6	31.75	2.26	257.28	1206.82
Meat	226.8	34.02	11.34	—	243.72
Oysters	226.8	12.52	2.04	—	70.01
Breakfast Cocoa	28.3	6.60	7.50	9.60	135.42
Milk	113.4	3.63	4.42	4.88	75.55
Broth	453.6	18.14	18.14	90.72	316.21
Sugar	28.3	—	—	27.36	112.17
Butter	14.17	.14	12.27	—	118.62
Total		106.80	57.97	389.84	2574.60

Here the amount of protein is nearly 107 g. or about the average suggested by the best authorities.

In studying dietaries, it is also a practical question to ascertain what the cost of food per day per man should be. The habits of people differ so widely, that while in some countries good and sufficient food can be obtained at 10 to 15 cents per day per capita, in other localities as much as 35 cents per day is needed to procure satisfactory food. The following summary [1] of cost of food in different localities, and under varying conditions of life, and showing the amount of food wasted, is of interest: —

	Cost of Food Purchased	Calories	Calories Wasted	Nutritive Ratio
	Cents			
Teacher's family, Illinois	27	3975	700	1 : 6.9
Professional men, Connecticut	25	3530	100	1 : 6.8
Mechanics' Boarding Club, Illinois	23	3720	330	1 : 6.1
Mechanic's family, Indiana	26	3840	555	1 : 7.9
Mechanic's family, Tennessee	16	4435	345	1 : 8.1
Students' Club, Kansas [2]	18	3437	—	1 : 7.6

[1] Bul. 91, U. S. Dept. of Agric., Bu. Chem., 1900.

[2] Trans. Kan. Acad. of Science, Vol. XIX.

As some of these figures were obtained several years ago, they would not indicate the cost of living at the present time, as similar experiments have shown that it has increased, within a few years, from 30 % to 60 %.

The waste of food referred to covers the necessary loss from skins, seeds, bones, etc.; and evidently, from the great difference in different cases, it also covers a large amount of unnecessary waste.

From statistics collected in this country, especially in Massachusetts, and in Europe, an idea can be obtained of the proportion of income that is ordinarily used for the purchase of food by families in different circumstances.[1] These figures will not, however, apply at the present time with the high cost of living: —

	Income	Per Cent expended for Food
Germany	Dollars	
Workingmen	225–300	62
Middle class	450–600	55
Well-to-do	750–1100	50
Great Britain		
Workingmen	500	51
Massachusetts		
Workingmen	350–400	64
Workingmen	450–600	63
Workingmen	600–750	60
Workingmen	750–1200	56
Workingmen	Above 1200	51

When the income is small, considerably more than one half is expended for actual food. This surely leaves a very

[1] Farmers' Bul. 23, U. S. Dept. Agric.

small amount for rent, clothing, and the other necessaries of life. Since a sufficient quantity of wholesome food is of the utmost importance, the poor man is justified in expending more than half of his income to provide his family with that which they need to give them health and strength. It is unfortunately true, however, that even the most intelligent people know less of the source, uses, and actual value of their food for fulfilling its important purpose than they do of almost any of the other daily necessities.

It is estimated that at least 10% of the income is squandered not only by the well-to-do, but frequently also by those who have a very small income and so can ill afford it, in expensive food material which affords little nutrition, in unsatisfactory methods of preparation, in selecting foods out of season, by throwing away much valuable food material, and by using badly constructed cooking appliances. Much careful investigation is needed along these economic lines, and painstaking instruction will ultimately improve these conditions which are at present so much deplored.

INDEX

A

Absinthe, 342.
Acetylene gas, 64.
Acetylene, solubility of, 65.
Acid, benzoic, in foods, 360.
  citric, 268.
  fruit, 227.
  in fruits, 329.
  lactic, 300.
  malic, in fruits, 266.
  oxalic, poisoning by, 156.
  salicylic, in foods, 360.
  sulfuric, poisoning by, 153.
  tartaric, in fruits, 268.
  tartaric, manufacture, 268.
Aconite poisoning, 159.
Activated sludge process, 109.
Activated sludge, utilization of, 110.
Aërated bread, 203.
Air, 1.
  a mixture, 5.
  ammonia in, 15.
  amount required, 48.
  argon in, 3.
  carbon dioxid in, 7, 10, 11, 12, 13.
  carbon monoxid in, 15.
  composition of, 4, 6.
  constituents of, table, 4.
  dry, as purifier, 143.
  dust in, 18, 19, 20, 21, 22.
  examination for dust, 19.
  experiments, 5.
  expired, 12.
  gas, 63.
  helium in, 4.
  history, 2.
  humidity, 7, 8, 9.
  hydrogen sulfid in, 16.
  microörganisms, 20.
  nitrogen in, 7.
Air, of crowded rooms, 11, 46, 47.
  of public buildings, 49.
  of the ground, 24.
  of vaults, 25.
  oxygen in, 2, 5, 6.
  ozone in, 16, 17.
  pure, 49.
  rare gases in, 4.
  rebreathed, 47.
  stagnant, 48.
  testing, 52.
  vitiated, 6.
  weight, 1, 2.
Aladdin oven, 370.
Albuminates, 281.
Albuminoids, 282.
Albuminous food cooking, 367.
Albuminous substances, function, 282.
Albumins, 281.
Alcohol, amount yielded, 340.
  as food, 343, 344.
  making, 340.
  physiological action, 342.
  properties, 327.
  wood, 38.
  wood as poison, 159.
Alcoholic beverages, 327.
  classified, 328.
  consumption, 327, 328.
Alcoholic liquor, use in baking, 202.
Algæ as food, 261.
Alkalies, poisoning by, 153.
Alkaloids, 157.
  in beverages, 326.
Almonds, 278.
  bitter, 278.
Alum baking powder, 209.
Alum in bread, 210, 227.
  tests for, 211.
Amides, 282.

Amido-acids, 282.
Ammonia in air, 15.
in water, 80, 81.
Ammonium carbonate, use in baking, 203.
Amygdalin, 278.
Angostura, 342.
Aniline blue, 138.
Animal food, 368.
amount used, 284.
Animal foods, use of, 280.
Annatto in cheese, 305.
Anthracite coal, 33.
Antimony, poisoning by, 155.
Antiseptics, 140.
Apples, composition, 264.
ripening, 264.
Argand lamp, 68.
Argol, 268.
Argols from wine, 330.
source, 205.
Argon in air, 3.
Aristotle's experiments, 1.
Arrowroot, 188.
Arsenic in wall paper, 23.
Arsenic poisoning treatment, 155.
Artesian water, 74.
Artificial silks, 118.
Ash in wood, 31.
Asparagin, 282.
Asparagus, 259.
Atmosphere, 1.
Atwater's experiments, 373.

B

Babcock tester, 297.
Bacteria, in sewage purification, 111.
multiplication of, 142.
Baking bread, methods, 219.
Baking, conditions, 217.
loss in, 218.
Baking powder, 205.
alum, 209.
cream-of-tartar, 207.
homemade, 212.
manufacture, 206.
phosphate, 208.
strength, 206.
Baking powder, valuation, 206.
Baking soda, 203.
Banana, composition, 192.
digestion, 193.
flour, 193.
Bananas as food, comparison, 192.
cost, 192.
cultivation, 191.
shipping, 192.
Barley, composition and use, 183.
Barometer, use, 2.
Beans and peas, cooking, 367.
Beef as food, 287, 288.
Beef extracts, 287.
Beer, 336.
adulteration, 338.
composition, 337.
preservatives in, 338.
small, 338.
Beet sugar, 241.
Beets, 258.
Begasse, 238.
Benedictine, 342.
Benzoate of sodium, 361.
Berries, composition, 265.
Beta-naphthol in food, 360.
Beverages, alcoholic, 327.
alcoholic, consumption, 327, 328.
non-alcoholic, 312.
non-alcoholic, amount imported, 312.
non-alcoholic, per capita consumption, 312.
stimulating, comparison, 325.
Bituminous coal, 33.
Blaugas, 64.
Bleached flour, 228.
Bleaching, 138.
agents used, 138.
powder as disinfectant, 148.
powder for water purification, 96.
Bluing, 136.
Bock beer, 338.
Body, composition of, 168.
Bone-black filters, use, 245.
Bone-black, revivifying, 245.
Borax in food, 360.
use in cleaning, 124.
Bran, use of, 223.

Brandy, 340.
Brass and copper cleaning, 127.
Bread, 201.
aërated, 203.
alum in, 227.
and milk, 223.
bad, 225.
brown, 225.
composition of, 221, 222.
copper sulfate in, 226.
crumb and crust, 222.
dark, 226.
fermented, 213.
fresh *vs.* stale, 220.
graham, 202.
making good, 217.
methods of raising, 202.
moldy, 225, 226.
non-fermented, 201.
nutritive value, 222.
overfermentation, 225.
salt-rising, 216.
unleavened, 202.
varieties, 223.
white, 226.
whole wheat, 202, 224.
Breakfast foods, 230, 232.
Briquettes, 34.
British Thermal Unit, 27.
Bunsen's experiments, 3.
Burners and lamps, 67.
Burners for gas, 36.
Burning fluid for lighting, 58.
Butter, 307.
adulteration, 310.
composition, 308.
fat, amount in milk, 297.
fat, composition, 296.
process, 308.
renovated, 308.
ripening, 307.
Butterine, 308, 309.

C

Cabbage, 258.
Cacao, growing seeds, 322.
Café au lait, 320.
Caffein, 323, 326.
Caffein, in coffee, 319.
Caffeol in coffee, 319.
Calcium carbid, use of, 65.
Calcium hypochlorite, in bleaching, 138.
as disinfectant, 148.
Calcium saccharate, 243.
Calorie, 27.
Calories, 372.
Calorimeter, respiration, 373.
Camphene for lighting, 58.
Candle flame, 55.
Candles, dipped, 58.
history, 56.
materials used, 57.
molded, 58.
Cane sugar, making, 238, 239.
Cannel coal, 33.
Canning, commercial process, 356.
food, 355.
methods used, 356.
objections to, 357.
Caramel, 247.
Carbohydrate foods, 170.
Carbohydrates, amount necessary, 376.
Carbolic acid as disinfectant, 145.
poisoning, 159.
Carbon dioxid in air, 7, 10, 11, 12, 13.
in closed rooms, 10, 11.
in respired air, 46.
qualitative determination, 12.
quantitative determination, 13, 14.
Carbon monoxid as poison, 160.
in air, 15.
Carbon tetrachlorid, use in cleaning, 125.
Carbonation, 242.
Carrots, 259.
Casein of milk, 299.
Cassava, 187.
Cassia, 346.
Castile soap, 131.
Cavendish, experiments by, 2.
Celery, 259.
Cellulose, 171.
digestion of, 171.

Centrifugals, 240.
Certified dyes, 363.
Chaptalising, 334.
Charcoal as deodorizer, 143.
  making, 31, 32.
Chartreuse, 342.
Cheese adulteration, 307.
  as food, 306.
  Brie, 305.
  Camembert, 305.
  Cheddar, 305.
  composition, 306.
  Edam, 306.
  Gorgonzola, 305.
  Gruyère, 305.
  Limburger, 306.
  making, 305.
  Neufchâtel, 305.
  Parmesan, 306.
  Roquefort, 306.
  Stilton, 305.
Chemical precipitation of sewage, 110.
Chemical preservatives, 358.
Chestnuts, 278.
Chevreul's experiments, 134.
Chloral hydrate, 159.
Chlorid of lime, early use as disinfectant, 148.
Chlorin in water, 82.
Chloroform poisoning, 159.
Chocolate, 321.
  bitter, 323.
  history, 321.
  nutritive value, 325.
  sweet, 324.
Cholin, 282.
Chondrin, 282.
Cider, 335.
  adulteration, 335.
  alcohol in, 335.
Cinnamon, 346.
Cities supplied by rivers, 100.
  water supply of, 98.
Citric acid in fruits, 268.
City water supplies, 84.
Cleaning, 123.
  powders, 123.
Closed rooms, carbon dioxid in, 10.
Cloves, 346.
Coagulation and sedimentation, 92.
Coal, 32, 33, 34.
  anthracite, 33.
  bituminous, 33.
  cannel, 33.
  lignite, 32.
  semianthracite, 33.
  semibituminous, 33.
Coal oil, 59, 60, 61.
Coals, analysis of, 34.
Coal-tar colors, 363.
Cocoa, 321.
  butter, 323.
  commercial preparations, 323.
  manufacture, 322.
  nibbs, 323.
  product, composition, 322.
  shells, 323.
  soluble, 324.
Cocoanut, 278.
  oil, 275.
Coffee, adulteration, 319.
  bad effect of boiling, 320.
  berry, curing, 318.
  berry, growing, 318.
  effect of, 325.
  history, 317.
  Java, 321.
  leaf tea, 317.
  making the beverage, 320.
  Mocha, 321.
  pulping, 318.
  raw and roasted, composition, 319.
  Rio, 321.
  roasting, 318.
  substitutes, 320.
  tannin in, 320.
  varieties, 321.
Coke, 34.
  petroleum, 34.
Cola, 324.
  effect on system, 326.
Collagen, 282.
Combustibles, 26.
Compound lard, 277.
Condensed milk, 302, 303.
Contents, ix.

Cooker, fireless, 370.
Cooking foods, 165.
  fruits, 269.
  meat, 284, 285.
  methods, 369.
Copper, as a poison, 154.
  in food, 364.
Copper sulfate, as disinfectant, 146.
  in bread, 226.
Cordials, 328, 342.
Corn, 179.
  as food, 180.
  composition, 180.
  nutritive value, 180.
  pones, 202.
Corrosive sublimate, use of, 150.
  use in wounds, 150.
Corrosives, 153.
Cost of food, 367.
Cottolene, 277.
Cotton, fire-proofing, 121.
  mercerized, 115.
  structure, 115.
Cottonseed oil, 275.
Cottosuet, 277.
Crackers, 222.
Cream of tartar, 268, 330.
  baking powder, 207.
  use in baking, 205.
Creatin, 283.
Cresols as disinfectants, 146.
Crowd poisoning, 47.
Crutcher, use of, 131.
Curacoa, 342.

D

Defecation, 245.
Deodorants, 140, 146.
Dew point, 8.
Dextrin, 195.
  properties, 196.
Dextrose from starch, 199.
Diet, change of, 164.
  of farmers, 377.
  mixed, 164.
Dietaries, 365, 370.
  standard, 373.
  studies, 373, 376.
Dietary, Chittenden, 377.
Dietary, Richards, 378.
Diffusion process, 241, 242.
Digestion of fats, 366.
  of starch, 365.
Disease germs, how destroyed, 147.
Disinfectant, ideal, 142.
  standardizing, 151.
Disinfectants, 140, 141.
  tests for, 141, 142.
  which destroy spores, 147.
Disinfection, by carbolic acid, 145.
  by sulphur dioxid, 144.
  of sewage, 110.
  of water, 95.
Distilled liquors, 339.
Dough raising, 201.
Draft avoided, 52.
Dried eggs, 293.
Dried milk, 303.
Drinking water and disease, 84, 85.
Dry air as purifier, 143.
Dry earth as purifier, 143.
Dust and tuberculosis, 21, 22.
Dust, effects of, 21, 22.
  in air, 18, 19, 20, 21, 22.
  in city streets, 20.
Dyes, certified, 363.

E

Economy of food, 369.
  fuel, 369.
Economy in preparation of food, 365.
Egg, substitutes, 293.
  white, composition, 291.
  yolk, composition, 291.
Eggs, annual production, 291.
  composition, 292.
  cooking, 293, 294.
  desiccated, 293.
  in the diet, 292.
  preservation, 292.
  use in baking, 202.
  weight, 291.
Elastin, 282.
Electric heating, 45.
Electric lights, 69.
Emulsion, 278.

Erbswurst, 191.
Ergot in rye, 228.
Essences, fruit, artificial, 273.
Evaporated milk, 302, 303.
Extracts, beef, 287.
flavoring, 272.

F

Fabrics, household cleaning, 125.
Faraday and candle flame, 55.
Fat, amount necessary, 376.
in food products, 274, 275.
Fats, digestion of, 366.
edible, 274.
for soap making, 130.
Fehling's test, 199.
Fermentation and decay, 355.
Fermentation, causes affecting, 216.
in bread, 218.
Fibrin, 282.
Filled cheese, 307.
Filter beds, use of, 108.
Filters for household use, 96.
Filtration, intermittent, of sewage, 107.
Fire to destroy disease germs, 147.
Fireless cooker, 370.
Fireplace, use of, 39, 40.
Fish, fat and lean, 288.
food value, 288.
water in, 289.
Flash-point apparatus, 61.
Flax structure, 116.
Flour, adulteration, 226.
analyses, 177, 178.
bleached, 228.
compound, 226.
entire wheat, 224.
germ, 224.
grades compared, 179.
graham, 224.
patent, 224.
wheat, 176, 177.
Food, accessories, 345.
albuminous, cooking, 367.
amount per day, 375, 376.
analysis, 170.
animal, amount used, 284.
Food, breakfast, composition, 232.
breakfast, use of, 232.
canning, 355.
cost per capita, 378.
defined, 161.
economy of, 369.
for infants and invalids, 229.
material needed, 166.
materials, composition, 371.
per cent of income expended for, 379.
predigested, 231.
preservation, 354.
products, coloring, 363.
waste, 379.
Foods, animal, 280.
breakfast, 230, 232.
carbohydrate, 170.
carbonaceous, 168.
character of, 166.
classification of, 168.
cooking, 165.
cost, 367.
early use of, 163.
economy and preparation, 365.
indigestible, 166.
nitrogenous, 168, 280.
selection of, 165.
starchy, 189.
starchy, adulteration, 189.
use of, 161.
wholesome or poisonous, 163.
Formaldehyde gas as disinfectant, 149.
Formaldehyde in food, 359, 362.
Formalin, use of, 149.
Franklin stove, 40.
Fruit essences, 273.
jelly, 266.
juices and alcohol, 328.
sirups, 272.
Fruits, composition, 265.
cooking, 269.
ripening, 263.
structure, 263.
sugar and acid in, 329.
taste of, 264.
Fuel gas, 36.
value, 372, 373.

Fuels, burning, 29.
constituents, 26, 27.
economy, 369.
gases, 28.
history, 26.
liquid and solid, 27.
Fungi as food, 261.
Furfurol in liquors, 342.
Furnace, air for use in, 42.
hot air, 41, 42.
Furnace air, moisture in, 42.
Fusel oil, 340.

G

Galileo, experiments, 1.
Garbage, disposal of, 103.
in refuse, 113.
Gas, acetylene, 64.
air, 63.
as fuel, 35.
burners, 36.
by-products, 62.
combustion of, 56.
illuminating, history, 62.
lights, incandescent, 68, 69.
manufacture, 62.
Pintsch, 64.
sand, 36.
water, 63.
Gases, fuel, 28.
illuminating, composition, 65.
in air, 15.
offensive, 25.
Gasoline, 37, 38.
vapor, 38.
Gelatin, 282.
Gin, 341.
Ginger, 347.
Glass cleaning, 125.
Globulins, 281.
Glucose, 251.
as food, 253.
commercial, 251, 252.
composition, 252.
healthfulness, 253.
uses, 252.
Gluten in wheat, 175.
Glycerin, 133.
Goiter and water supply, 78.
Graham flour, 224.
Granulated sugar, 247.
Granulator, 246.
Grape sugar, 251.
making, 252.
Grapes for wine, 330.
Grates, open, 51.
Grease, solvents for, 124, 126.
Great Lakes as water supply, 99.
Greens, 259.
Ground air, 24.
Ground water supplies, 101.
Gums, 196.

H

Hamburg cholera epidemic, 87, 88.
Hard waters, 77, 78.
Heat, effect on meat, 285.
for disinfecting, 144.
units, 371.
Heating, by hot water, 43, 44.
by steam, 43.
electric, 45.
Heating and ventilation, 39.
Helium in air, 4.
Honey, 255.
adulteration, 256.
composition, 255.
Hot-air furnace, 41, 42.
Hot-water heaters, 43, 44.
Household purification of water, 96.
Household waste disposal, 111.
Humidity of air, 7, 8, 9.
Hydrochloric acid, use in baking, 204.
Hydrocyanic acid, poisoning, 156.
Hydrogen peroxide, as disinfectant, 147.
in air, 16.
in bleaching, 138.
Hydrogen sulfid in air, 16.
Hydrolysis of starch, 199.

I

Iceland moss, 261.
Ideal ration, 377.
Illuminating devices, early, 56.
Illuminating gas, 62.

Imhof tank, use of, 108.
Incandescent gas lights, 68, 69.
Income squandered, 380.
  vs. food, 379.
Indigo blue, 136.
Infant's food, 229.
Infants' foods, 223.
Injurious traits, 23.
Ink spots, removing, 127.
Introduction, xxv.
Inulin, 196.
Invalid's food, 229.
Invert sugar, 254.
Irish moss, 261.
Iron stains, removing, 127.
Iron sulfate as disinfectant, 146.

J

Jams and their adulteration, 270.
Jellies and their adulteration, 270.
Jelly, coal-tar dye in, 271.
  from fruit, 266.

K

Kerosene, 38.
  fire test, 61.
  flash-point, 61.
  history, 59.
  purification, 60.
Knowledge of food lacking, 380.
Koumiss, 298.
Kümmel, 342.

L

Lactometer, use, 296.
Lactose, 250.
Lager beer, 338.
Lake water, 73.
Lakes for public water supplies, 99.
Lamps and burners, 67.
Lard, 276.
  compound, 277.
  kettle rendered, 276.
  neutral, 276.
  refined, 276.
Lausen epidemic, 88.
Lavoisier's experiments, 2.
Lead salts as poison, 154.
Leather cleaning, 125.
Leaven, use of, 215.
Leaves and stalks as food, 258.
Lecithin, 282.
Legumes, composition, 190.
  digestion, 190.
  history, 189.
  use as food, 189, 191.
Legumin, 190.
Lemon extract, 273.
Lettuce, 259.
Levulose, 255.
Lichens as food, 261.
Light efficiencies, 70.
Light-producing substances, 54.
Light, sources of, 54.
Lighting, 54.
  systems, 70.
Lights, electric, 69.
Lignite, 32.
Linen, 116.
Liqueurs, 342.
Liquor, 328.
Liquors, adulteration, 341.
  distilled, 328, 339.
  fermented, 328.
  malt, 328.

M

Macaroni, 233.
  composition, 233.
  nutritive value, 234.
Mace, 347.
Malic acid in fruits, 266.
Malt, 336.
  liquors, composition, 337.
  manufacture, 336.
  pale, 336.
Maltose, 250.
Mantles, life of, 69.
Maple sirup, adulteration, 243.
Maple sugar, 243.
Maraschino, 342.
Marble cleaning, 125.
Marc, 330.
Margarin, 308.
Mashing, 336.

Masse cuite, 240, 254.
Maté, 317, 325.
Meat, diseases, 289.
  effect of cooking, 284.
  extractives, 284.
  jerked, 355.
  nutritive value, 387.
  parasites in, 289.
  roasting, 286.
  smoked, 355.
  stewing, 286.
  structure, 283.
Mechanical filtration, 92, 94.
Mercerized cotton, 115.
Mercuric chlorid as disinfectant, 150.
Mercury poisoning treatment, 155.
Mercury salts as poisons, 155.
Messina epidemic, 86.
Methyl alcohol poisoning, 159.
Microbe killer, 141.
Milk, adulteration, 304.
  amount used, 295.
  ash, 301.
  casein in, 299.
  condensed, 302.
  dried, 303.
  evaporated, 302.
  fat, standard, 297.
  formaldehyde in, 304.
  modified, 250, 303.
  of various animals, composition, 296.
  pasteurized, 301, 302.
  proteins, 300.
  sour, use in baking, 204.
  souring, 300.
  specific gravity, 296.
  sterilized, 301.
  sterilized, changes in, 301.
  structure, 295.
  sugar, 250, 300.
Millet, 183.
Milwaukee sewage system, 106.
Mineral substances in water, 75.
Mineral waters, 75.
Modified milk, 303.
Moisture, in air, 7, 8.
  in furnace air, 42.
Molasses, 244.
Morphine as poison, 157.
Morphine poison treatment, 158.
Moss, Iceland, 261.
  Irish, 261.
Mucin, 282.
Municipal refuse, 112, 113.
Muscles, structure, 283.
Mushrooms, 261.
  poison, 262.
Must, 330.
Mustard, adulteration, 348.
  black, 348.
  oil of, 348.
  white, 348.
Myosin, 282, 283.

N

Natural gas, 35, 36.
  composition, 37.
Nessler's solution, 83.
Neutral, use in butterine, 309.
Nitrates in water, 81.
Nitrites in water, 81.
Nitrogen balance, 377.
Nitrogen in air, 7.
Nitrogenous substances, classification, 281.
Non-alcoholic beverages, 312.
Nuclein, 282.
Nutmeg, 347.
Nutritive ratio, 375.
Nuts, composition, and food value, 277.

O

Oatmeal, cooking, 182.
  use as food, 181.
Oats, composition, 181.
Odor killers, 144.
Oil, cocoanut, 275.
  cottonseed, 275.
Oil lamps, 58.
Oils, edible, 274.
Oleomargarin, making, 308.
  production, 310.
  tax, 309.
Oleo-stearin, 309.

Onions, 260.
Oven, brick, 219.
  temperature, 213.
Oysters, 289.
Oxalic acid, poisoning, 156.
Oxygen in air, 6.
Ozone, composition of, 17.
  history, 16.
  in air, 16, 17.
  test, 17.

P

Paint removing, 126.
Paraffin, 58, 60.
  removing, 126.
Paraform for disinfecting, 149.
Paraguay tea, 317.
Parsnips, 257.
Pascal, experiments on air, 2.
Peanut, 279.
Peas in the diet, 191.
Peat, charcoal from, 32.
  occurrence, 32.
  water in, 32.
Pectin, 266.
Pepper, 347.
Peptones, 282.
  in meat, 283.
Perry, 336.
Petroleum coke, 34.
  distillates from, 60.
  distillation of, 59.
  pipe lines, 59.
Phosphate baking powder, 208.
Phosphorus poisoning, 157.
  treatment, 159.
Pintsch gas, 64.
Plantain meal, 193.
Plaster of Paris in wines, 333.
Plymouth, Pa., epidemic, 86.
Poison, definition, 153.
Poisoning, by alkali or acids, 153.
  arsenic, 155.
  mercury, 155.
  morphine, 157.
  phosphorus, 157.
  prussic acid, 156.
  strychnin, 158.
Poisonous gases, 160.
Poisons and their antidotes, 152.
Poisons, chronic and acute, 153.
  instructions for treatment, 152.
  metallic, symptoms, 154.
Pomace, 335.
Potassium permanganate, 146.
Potato, structure, 186.
  sweet, 187.
  waste, 186.
Potatoes as food, 186, 187.
  composition, 185.
  history, 185.
  production, 185.
Preface to First Edition, v.
Preface to Fourth Edition, vii.
Preservation of eggs, 292.
Preservatives, chemical, 358.
  danger of, 358, 359.
Pressure blowers for ventilation, 51.
Priestley, experiments on air, 2.
Proof spirit, 327.
Protein, amount necessary, 376.
Proteins, 281.
Proteoses, 282.
  in meat, 283.
Proximate principles, 168.
  substances, 169.
Prussian blue, 137.
Prussic acid poisoning, 156.
Ptomaine poisoning, 160.
Pulse, 189.
Purification of water supplies, 90.

Q

Quick process vinegar, 349, 350.
Quicklime for disinfection, 144.

R

Radiation, direct, 39.
  direct-indirect, 44.
  indirect, 41.
Ramsay, experiments, 3.
Ratafia, 342.
Ration, ideal, 377.
Rayleigh, experiments of, 3.
Refuse, municipal, 112–113.
Rennet, use, 299, 300, 305.

Renovated butter, 308.
Reservoirs, water collected in, 98.
Respiration, amount of air used, 46.
Respiration calorimeter, 373.
Rhubarb, 260.
Rice, composition, 184.
  growing, 183.
  polishing, 184.
  production, 184.
Ripening of fruits, 263.
River water, 72.
Rivers as water supplies, 100.
Rochelle salt, 205.
Roots as food, 257.
Rum, 341.
Rutherford, experiments on air, 2.
Rye, composition, 182.

S

Saccharin, 236.
  in food, 360, 362.
Sago, 188.
Saké, 338.
Salicylic acid in food, 360, 361.
Salt, composition, 353.
  manufacture, 352, 353.
  where found, 352.
Salt-rising process, 215.
Sand filtration, rapid, 92, 93, 94.
  slow, 92, 93.
Saponification, 129.
Sauerkraut, 259.
Schönbein's experiments, 16.
Scheele, 2.
Scurvy in meat eaters, 289.
Semianthracite coal, 33.
Semibituminous coal, 33.
Separator, use of, 298.
Septic tank, use of, 108.
Sewage, chemical precipitation, 110.
  composition, 104.
  definition, 104.
  disinfection of, 110.
  disposal, 103, 105.
  disposal of, by dilution, 106.
  farming, 107.
  method of treatment, 105.
Sewer gas, 25.
Silk, cuprammonium, 119.
Silk, structure, 118.
Silks, artificial, 118.
  manufacture, 118.
Silver cleaning, 127.
Small beer, 308.
Smell and taste, cultivation, 162.
Soap boiling, 130.
  castile, 131.
  dried, 134.
  floating, 133.
  ingredients, 129.
  lime, 134.
  manufacture, 128, 129.
  mottled, 132.
  powders, 136.
  sand, 132.
  silicated, 132.
  soft, 133.
  toilet, 132.
  transparent, 133.
  yellow, 131.
Sodium benzoate, in food, 360, 361.
Sodium bicarbonate in baking, 203.
Sodium sulfite, 361.
Softening water, 94.
Soft soap, 133.
Solids in milk, 299.
Sorghum sugar, 244.
Sour milk, 300.
Spaghetti, 233.
Spices, adulterants, 345.
Spring water, 72.
Stale bread, 220, 224.
Standard dietaries, 376.
Starch, chemical properties, 197.
  commercial, 193, 194.
  commercial sources, 174.
  cooking, 197.
  digestion, 365.
  grains, 197.
  hydrolysis, 199.
  methods of making, 193, 194.
  physical properties, 196.
  sources, 173, 174.
  with diastase, 200.
  with nitric acid, 200.
Starchy foods, 189.
Steam heat, 43.
  for destruction of germs, 147.

Steamer, use of, 370.
Stearic acid, 57.
Stimulating beverages, 325.
Stove, heating by, 41.
Stoves, ventilation with, 40, 41.
Strychnin, poisoning by, 158.
Sucrose, 237.
Sugar, amount consumed, 249.
as food, 235.
classification, 236.
commercial, 246.
composition, 248.
consumption, 236.
cut or cube, 247.
food value, 249.
from beets, 241.
granulated, 247.
grape, 251.
in fruits, 329.
in grape juice, 330.
invert, 254.
loaf, 246.
malt, 250.
maple, 243.
milk, 250.
of milk, 300.
powdered, 247.
production, 241.
properties of, 247.
refining, 244.
sorghum, 244.
Sugar cane, 236.
Sugar cane growing, 238.
Sugars, classification, 235.
history, 235.
source, 237.
Suint in wool, 117.
Sulfur dioxid in bleaching, 139.
for disinfection, 144.
Sulfurous acid in food, 260.
Sunlight as disinfectant, 143.
Sweet chocolate, 324.
Sweet potatoes, 187.
Synthetic foods, 166.

T

Tannin in coffee, 320.
Tapioca, 187.
Tapioca, preparation of, 188.
Tartaric acid in fruits, 268.
Taste and smell, cultivation of, 162.
Taste, delicacy of, 162.
Tea, adulteration, 314.
effect of, 325.
facing, 314.
green and black, 313.
growing and curing, 313.
history, 313.
lie, 315.
making beverage, 316.
Paraguay, 317.
varieties, 315.
Teas, composition, 315.
Tees valley, epidemic, 86.
Textile fibers compared, 119, 120.
Textiles, 114.
reactions with acids and alkalies, 120, 121.
Thein in tea, 316.
Theobromine, 323, 326.
Tomato catsup, 260.
Tomato, history and composition, 260.
Torricelli's experiments, 1.
Trades, injurious, 23.
Triple-effect pans, 239.
Truffles, 261.
Tuberculosis and dust, 21, 22.
Turnips, 258.
Typhoid bacillus, 89.
Typhoid fever and water supply, 86, 87, 88.
Tyrotoxicon in cheese, 307.

U

Ultramarine blue, 137.

V

Vacuum cleaners, 22.
Vacuum pan, 239.
Vanilla extract, 272.
Vegetable food, 368.
Ventilating and heating, 39.
Ventilating devices, 52.
Ventilation, by gas jet, 51.

Ventilation, by exhaust fans, 50.
by natural or forced draft, 50.
by pressure blowers, 50.
downwards or upwards, 50.
importance of, 45, 46.
Vermicelli, 233.
Vermuth, 342.
Vinegar, 348.
chemical changes, 348, 349.
cider, 350.
eels in, 350.
imitation, 351.
making, 348.
materials used, 349.
quick process, 349, 350.
strength, 351.
use, 351.
wine, 350.
Viscose, 119.
Vitiated air, 6.

W

Wall paper, arsenic in, 22, 23.
Waste, household, 111.
Water, ammonia in, 80, 81.
artesian, 74.
artificial purification, history of, 91.
boiling to purify, 96.
boiling for disinfection, 148.
carriage of sewage, 103.
chlorin in, 82.
cistern, 72.
disinfection of, 95.
Water gas, 63.
Water, household, purification, 96.
impurities in, 85.
in wood, 30.
mineral substances in, 75.
municipal filtration, 92.
natural purification, 90.
nitrates in, 81.
nitrites in, 81.
of wells, 73, 74.
purification by iron, 97.
sanitary analysis, 80.
spring, 72.
freezing for purification, 97.
Water, organic matter in, 79.
purified by oxidation, 90.
river, 72.
sources, 71.
softening, 94.
supplies, city, 84.
supplies from rivers, 100.
vapor in air, 7, 8, 9.
Waters, hard, 77, 78.
mineral, 75.
permanently hard, 77.
temporarily hard, 77.
Well water, 73, 74.
Welsbach system, 68.
Wheat, analysis of, 176.
composition, 175.
hard and soft, 175.
proteins in, 195.
structure, 174.
varieties, 176.
Whisky, 341.
Whole wheat bread, 224.
Wine, aging, 331.
composition, 332.
making, 330.
old, 331.
pasteurization, 331.
production, 334.
storage of, 330.
strength, 331.
where grown, 339.
Wines, adulteration, 333.
classification, 332.
dry, 333.
fortified, 332.
high, 340.
plastering, 333.
red and white, 332.
still, 333.
sweet, 332, 333.
Wood alcohol, 38.
Wood ashes, 31.
as fuel, 29.
kiln-dried, 30.
water in, 30.
Wool grease, 117.
structure, 117.
Workingmen, food of, 379.
Wort, 337.

X

Xanthin, 283.

Y

Yeast, brewers', 214.
cakes, 215.
Yeast, compressed, 214.
domestic, 214.
use of, 213.

Z

Zinc salts as poison, 154.

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TABLE OF CONTENTS

PART I

Food Values and Food Requirements.

The Composition of Food Materials.
The Functions of Food.
- Food as a Source of Energy.
- Food as Building Material.
- Food in the Regulation of Body Processes.

Food Requirement.
- The Energy Requirement of Normal Adults.
- The Energy Requirement of Children.
- The Energy Requirement of the Aged.
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- The Fat and Carbohydrate Requirement.
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Relation between Percentage Composition and Weight.
Calulation of the Fuel Value of a Single Food Material.
Calculation of the Weight of a Standard or 100-Calorie Portion.
Food Value of a Combination of Food Materials.
Distribution of Foodstuffs in a Standard Portion of a Single Food Material.
Calculation of a Standard Portion of a Combination of Food Materials.
Analysis of a Recipe.
Modification of Cow's Milk to a Required Formula.
Calculation of the Percentage Composition of a Food Mixture.
The Calculation of a Complete Dietary.
Scoring of the Dietary.

Reference Tables.

Refuse in Food Materials.
Conversion Tables — Grams to Ounces.
Conversion Tables — Ounces to Grams.
Conversion Tables — Pounds to Grams.
Food Values in Terms of Standard Units of Weight.
Ash Constituents in Percentages of the Edible Portion.
Ash Constituents in Standard or 100-Calorie Portions.

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